AL.2.1986-288

AN ANALYSIS OF BENTHIC INVERTEBRATE AND WATER QUALITY MONITORING DATA FROM THE ATHABASCA RIVER

RMD Report L-91

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Walder, G.L. and D.W. Mayhood. 1985. An analysis of benthic invertebrate and water quality monitoring data from the Athabasca River. Prep. for Alberta Environment, Research Management Division by Sigma Biometrics and FWR Freshwater Research Limited. RMD Report L-91. 254 pp.

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AN ANALYSIS OF BENTHIC INVERTEBRATE AND WATER QUALITY MONITORING DATA FROM THE ATHABASCA RIVER

by

G.L. WALDER
Sigma Biometrics

and

D.W. MAYHOOD
FWR Freshwater Research Ltd.

for

RESEARCH MANAGEMENT DIVISION
Alberta Environment

1985

EXECUTIVE SUMMARY

As a result of industrial development in the Athabasca oil sands area of northeastern Alberta, concerns have been raised regarding potential impacts on surface water quality in the area. It is of particular concern that the cumulative effects of increasing development of the oil sands may create hydrocarbon and metal pollution problems in the Athabasca River.

With the aims of evaluating baseline water quality conditions and identifying areas that may have been affected by existing industrial developments, water quality of the Athabasca River within the oil sands area has been monitored since 1976. In addition, several studies of benthic invertebrate communities have been conducted and these provided primarily descriptive information.

This report presents a detailed statistical analysis of water quality and benthic invertebrate data from previous studies on the Athabasca River. Benthic invertebrate data were from a study conducted in 1981 on the Athabasca River between Fort McMurray and the Tar River confluence. Water quality data for the same area were obtained from the NAQUADAT water quality data base for the period 1976 to 1983. The study area includes a 75 km section of the Athabasca River extending from the confluence with the Horse River upstream of Fort McMurray, downstream to the confluence with the Tar River, approximately 40 km downstream from the Suncor extraction and upgrading plant. Six water quality monitoring stations and eight benthic invertebrate sampling stations were located within the study area.

The relationships among various water quality parameters were examined using the methods of principal component analysis. Principal components were also used to describe associations of benthic invertebrate taxa and for transformation of abundance data prior to making statistical comparisons among sampling stations. The relationships between water quality and benthic invertebrates were examined by determining the correlations of benthic invertebrate principal components with water quality principal components.

Strong correlations among several of the water quality parameters were apparent. Most of the major ions (calcium, magnesium, sodium, chloride, sulphate, and bicarbonate) were strongly correlated with each other and with specific conductance, total alkalinity, and filterable residue. Potassium concentrations were independent of the concentrations of other major ions. There were also components of sodium and chloride, attributable to the clerwater River and other east bank tributaries, that were not strongly related to the concentrations of other ions. All of the metals except lead and mercury were associated with non-filterable residue and total phosphate.

With respect to those water quality parameters included in the analyses, there was no evidence that effluent from the Suncor plant had a large or consistent effect on the water quality of the Athabasca River downstream from the development. The suggestion is that any effects on water quality were short-term in nature and did not result in changes that persisted for long periods of time.

The major differences in water quality and in benthic invertebrate abundance and community composition within the study area were between the left and right sides of the Athabasca River. These differences were considered to be due primarily to the influences of the Clearwater River and other east bank tributaries. Some observed differences in benthic invertebrate abundance and community composition within the study area may be related to nutrient enrichment from the Fort McMurray sewage effluent. There was no evidence of large differences in benthic invertebrate populations between stations immediately upstream and downstream of the Suncor development that could be attributed to the Suncor effluent.

The abundance of a variety of benthic invertebrate taxa appeared to be correlated with several water quality parameters. In most cases, these correlations were with water quality parameters that show differences between the left and right sides of the Athabasca River. The observed correlations therefore may be due to drifting of, and colonization by, invertebrates from the Clearwater

River, and possibly other right bank tributaries, rather than to any direct influence of water quality.

The results of statistical analyses of the benthic invertebrate data presented in this report must be considered tentative or inconclusive. A non-random selection procedure was used during collection of the benthic invertebrate samples and this adversely affects the validity of statistical analyses. The reliability of the results is therefore questionable.

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ABSTRACT

A detailed statistical analysis of water quality and benthic invertebrate data from previous studies on the Athabasca River was undertaken. Benthic invertebrate data were from a study conducted in 1981 on the Athabasca River between Fort McMurray and the Tar River confluence. Water quality data for the period 1976 to 1983 were obtained from the NAQUADAT water quality data base.

Principal component analysis was used to examine the relationships among various water quality parameters and was also used for transformation of benthic invertebrate abundance data prior to making statistical comparisons among sampling stations. The relationships between water quality and benthic invertebrates were examined using correlation analyses.

Strong correlations among several of the water quality parameters were apparent. Most of the major ions were correlated with each other and with specific conductance and filterable residue. Potassium concentrations were independent of the concentrations of other major ions. All of the metals except lead and mercury were associated with non-filterable residue and total phosphate.

The major differences in water quality and in benthic invertebrate abundance and community composition within the study area were between the left and right sides of the Athabasca River. These differences were considered to be due primarily to the influences of the Clearwater River and other east bank tributaries. Due to the use of a non-random selection procedure during collection of benthic invertebrate samples, the results of statistical analyses based on these data must be considered inconclusive.

ACKNOWLEDGEMENTS

We would like to express our appreciation to the following individuals for their helpful suggestions and assistance with various aspects of the project: Barry Munson, Cindy Jardine and Theo Beukeboom, all of the Research Management Division, Alberta Environment; Lynda Corkum, of the Water Quality Control Branch Pollution Control Division, Alberta Environment; and Hans Boerger, of Syncrude Canada Ltd. Lynda Corkum, Hans Boerger and Dave Tren reviewed the draft report. Funding for this study was provided by the Research Management Division, Alberta Environment.

We also thank Cyndy Clarke and Janice Hoover, who provided expert word processing services during the preparation of the final report.

1. INTRODUCTION

As a result of industrial development in the Athabasca oil sands area of northeastern Alberta, concerns have been raised regarding potential impacts on surface water quality in the area. It is of particular concern that the cumulative effects of increasing development of the oil sands may create hydrocarbon and metal pollution problems in the Athabasca River.

With the aims of evaluating baseline water quality conditions and identifying areas that may have been affected by existing industrial developments, water quality of the Athabasca River within the oil sands area has been monitored since 1976. Water quality data are maintained on the NAQUADAT storage and retrieval system, and the results of the monitoring program up to 1981 have been reported by Akena (1982).

In addition, studies of benthic invertebrate communities have been conducted at infrequent intervals (Flannagan 1976; McCart et al. 1977; Barton and Lock 1979; Barton 1980; Boerger 1983). These studies provided primarily descriptive information, and there has been no attempt to examine relationships between water quality and benthic invertebrate abundance and community composition.

The present study is concerned with a 75 km section of the Athabasca River extending from the confluence with the Horse River upstream of Fort McMurray, downstream to the confluence with the Tar River, approximately 40 km downstream from the Suncor extraction and upgrading plant. Wastewater effluents entering the river in this area include effluent from the Fort McMurray sewage treatement plant located on the west side of the river, the Suncor plant discharges, which also enter on the west side of the river across from the mouth of the Steepbank River, and water from the Syncrude diversion, which enters the Athabasca River through Poplar Creek, approximately 9 km upstream of the Suncor effluent outfall. Water from the Syncrude diversion is reported to be a minor influence, but may contribute some salt loading. Effluent from the sewage treatment plant contributes significant nutrient loadings (orthophosphate phosphorus and ammonia) as well as a variety of organic compounds including oil, grease, phenolic material, and other aliphatic and aromatic hydrocarbons to the Athabasca River (Akena 1982). The Suncor plant discharges ammonia, aliphatic and aromatic hydrocarbons, oils, greases, phenol, and sulphide into the river (Akena 1982; Boerger 1983). In addition, hydrocarbons enter the river from natural sources as a result of weathering of oil sands that are exposed at many locations along the banks of the Athabasca River and the banks of its tributaries. Discharge from the sewage lagoons at Fort McMurray occurs every month throughout the year. Release from sewage lagoons and Suncor occurs only during the open water season, and the releases may be interrupted.

The major tributary in the study area is the Clearwater River, which enters the Athabasca River at Fort McMurray. The Clearwater River contributes 13 to 29% of the annual flow of the Athabasca River, and no other tributary in the study area accounts for more than 30% of the mean annual flow (Boerger 1983). There is poor lateral mixing of the Athabasca River downstream from Fort McMurray, and water from the Clearwater River remains on the east side as far downstream as the Suncor plant, where there is a sharp bend in the river (Boerger 1983). Marked differences in sodium and chloride concentrations between the east and west sides of the Athabasca River have been observed downstream from Fort McMurray and were attributed to higher sodium chloride levels in east bank tributary streams (particularly the Clearwater River) and to inflows from saline reservoirs located along the east bank of the Athabasca River (Akena 1982).

This report presents an analysis of Athabasca River water quality data from 1976 to 1983 and of benthic invertebrate data collected during 1981. Correlations among selected water quality parameters are examined and seasonal and spatial differences in water quality are described. Benthic invertebrate abundance and distribution data (from Boerger 1983) are analysed in detail with reference to water quality and to sources of wastewater effluents. Correlations between water quality and benthic invertebrate abundance and community composition are examined.

2. MATERIALS AND METHODS

2.1 DATA SOURCES

Water quality data for seven stations on the Athabasca River were obtained from the NAQUADAT storage and retrieval system for the period 1976 to 1983. These data were provided on magnetic tape by the Water Quality Control Branch, Alberta Environment.

Benthic invertebrate sampling was conducted at eight stations in the study area at two-week intervals during the spring and summer of 1981. The results of that study have been reported by Boerger (1983). Benthic invertebrate data used for the present study were taken from an appendix to that report.

2.2 SAMPLING LOCATIONS AND SCHEDULES

2.2.1 Water Quality

Six stations on the Athabasca River within the study area have been sampled as part of the regular water quality monitoring program conducted by the Pollution Control Division, Alberta Environment. The station identification numbers and their locations as given by Akena (1982) are as follows: Station CC0012, 100 m upstream from the confluence with the Horse River; Station DA0203, at Mile 19 (just above the confluence with Poplar Creek); Station DA0205, at Mile 29.8 (approximately 7 km downstream from the Suncor effluent outfall); Station DA0206, at Mile 34.5 (just upstream from the confluence with the Muskeg River); Station DA0207, at Fort MacKay (below the confluence with the MacKay River); Station DA0208, at Mile 52.4 (approximately 4 km downstream from the confluence with the Tar River). One additional station (DD0010, at the WSC gauge at Embarras Airport), which is located a considerable distance downstream from the study area, was also included in analyses examining the correlations among water quality parameters.

The locations of three of the stations (DA0205, DA0207, and DA0208) apparently have been changed from those given above. The following information on the locations at which these stations are currently sampled was provided by Lynda Corkum (Pollution Control

Division, Water Quality Control Branch, Alberta Environment). Station DA0205 is now located immediately below the Suncor effluent outfall, approximately 7 km upstream from its former location. Station DA0207 is currently sampled just above the confluence with the MacKay River rather than below it. The present location of Station DA0208 is upstream from the confluence with the Tar River, 4 to 5 km upstream from the earlier location. We were not able to ascertain when these changes were made. However, statements made by Boerger (1983) regarding the correspondence between his benthic invertebrate sampling stations and water quality stations suggest that the locations of stations DA0207 and DA0208 in 1981 were the same as the present locations. The locations of the water quality monitoring sites are shown on Figure 1.

All of the water quality stations except DD0010 were sampled regularly during 1976 and into early 1977. Stations CC0012 and DA0207 were also monitored from mid-1977 through 1983. Station DD0010 was monitored regularly from late 1978 through 1983. Station DA0206 was not sampled from 1977 through 1979, but has been sampled regularly since 1980. Stations DA0203 and DA0208 were not monitored from 1977 through 1980. Station DA0203 was sampled regularly from 1981 through 1983 and Station DA0208 was sampled regularly in 1981 and 1983, but not for most of 1982. Station DA0205 was not monitored from 1977 through 1981, but was monitored regularly during 1982 and 1983. During the periods in which a station was monitored, sampling was generally on a monthly basis, but there are often gaps of several months (usually during winter) in the records for stations CC0012 and DD0010. In the spring and summer of 1981, stations CC0012, DA0203, DA0206, DA0207, and DA0208 were sampled at two-week intervals on dates coinciding with the benthic invertebrate sampling program.

During the period 1976 to 1983, 538 water samples were taken from the stations and 68 water quality parameters were measured. Not all parameters were determined for every sample, however, and for any one sample, the number of parameters measured was usually much less.

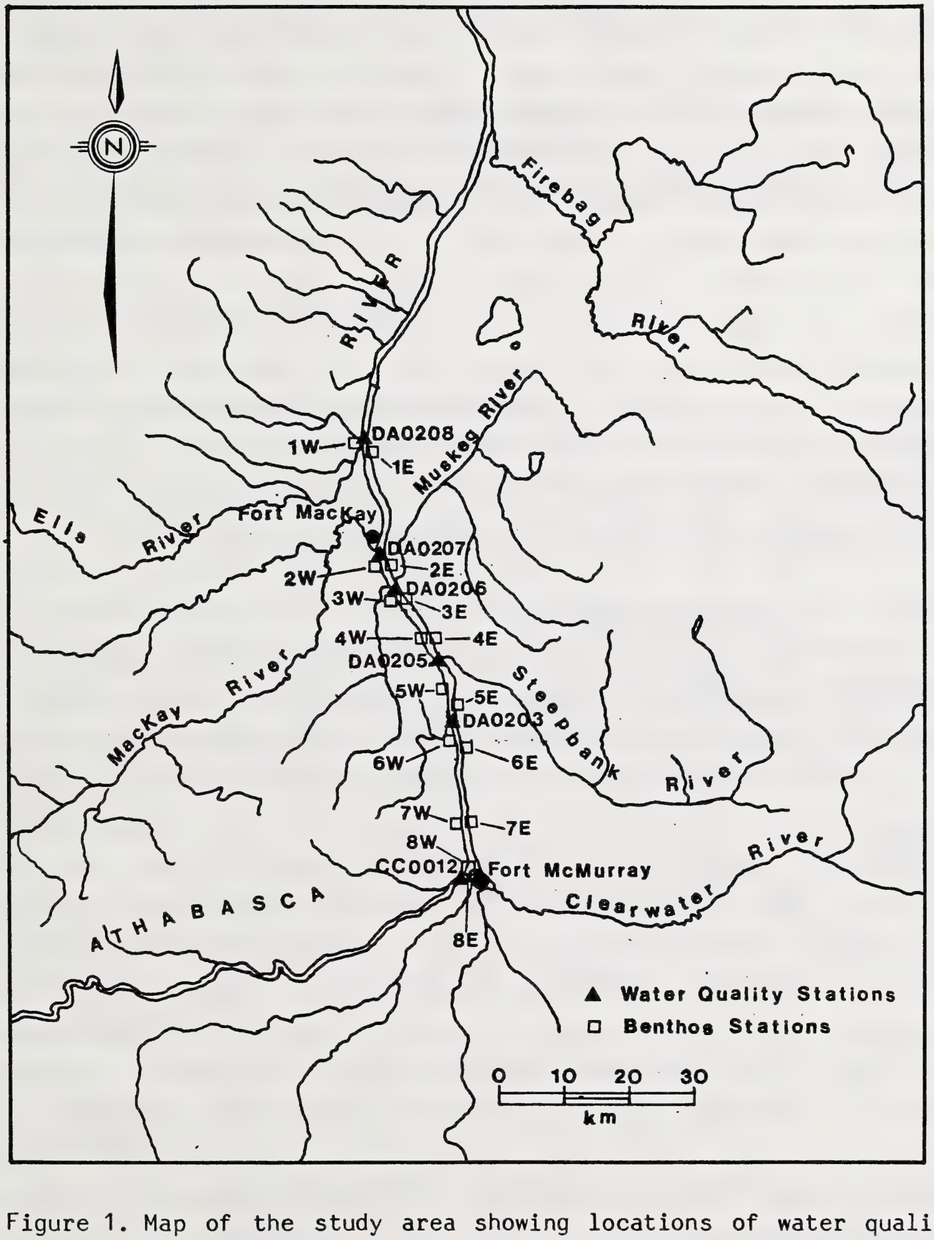

Figure 1. Map of the study area showing locations of water quality monitoring sites and benthic invertebrate sampling stations.

After 1983, the monitoring program at most of the stations generally included samples taken on both the left and right sides of the river (looking downstream). Stations CC0012 and DD0010 were usually sampled only at mid-channel. The location in the river channel was indicated by distances to the left and right banks, and the distance to the closest bank for samples apparently taken as left or right bank samples ranged from 1 m to approximately one-third of the river width. In the present study, samples located anywhere within the left 34% of the river width were considered left bank samples, those within the right 34% were considered right bank samples, and those within the central 32% were considered mid-channel samples. For 105 of the 538 water samples, there was insufficient information in the NAQUADAT files to determine sampling location. These samples were assumed to be mid-channel samples.

2.2.2 Benthic Invertebrates

The eight stations on the Athabasca River sampled for benthic invertebrates by Boerger (1983) during 1981 were as follows: Station 1, between the Tar River and Ells River confluences; Station 2, above the confluence with the MacKay River; Station 3, approximately 2 km upstream from the confluence with the Muskeg River; Station 4, approximately 4 km downstream from the Suncor effluent outfall; Station 5, upstream of the Suncor development and below the confluence with Poplar Creek; Station 6, approximately 5 km upstream from the confluence with Poplar Creek; Station 7, approximately 6 km downstream from Fort McMurray; Station 8, near the confluence with the Horse River, upstream of Fort McMurray. The locations of these stations are indicated on Figure 1. At each station, samples were taken from gravel bars on both the east (right) and west (left) sides of the river, giving a total of 16 sites (designated 1E and 1W through 8E and 8W).

A cylinder sampler was used, and three samples were taken from each of the 16 sites at each sampling interval. Sampling was conducted at two-week intervals on the following dates in 1981: May 13 and 14, May 28 and 29, June 9 and 10, June 23 and 24, July 7 and

8, July 21 and 22, August 4, and August 18 and 19. The August 4 sampling was incomplete, and the data for that interval were not used in the present study.

Five of the stations were located at or near water quality monitoring stations. Benthic invertebrate stations 1, 2, 3, 6, and 8 correspond to water quality stations DA0208, DA0207, DA0206, DA0203, and CC0012, respectively.

2.3 STATISTICAL METHODS

2.3.1 Principal Component Analysis

Principal component analysis (PCA) was used as an initial step in the analysis of both water quality and benthic invertebrate data. Application of PCA to water quality data was used to examine the relationships among various water quality parameters and to reduce the number of variables for subsequent analyses. With benthic invertebrate data, PCA was used primarily as a data reduction transformation to allow use of fewer variables in subsequent statistical analyses. All principal component analyses were performed using the BMDP Statistical Software package of computer programs (Dixon et al. 1981).

The method of principal component analysis is described in detail by Morrison (1976) and Johnson and Wichern (1982). Green (1979) discusses applications of PCA in environmental studies. The following introductory description is adapted from Marriott (1974) and Morrison (1976).

Principal component analysis transforms a set of variables $X_1 \ldots X_p$ to a new set of variables $Y_1 \ldots Y_p$ having the following properties:

1. Each new variable (principal component) is a linear combination of the original variables; for example $Y_i = a_{i1}X_1 + a_{i2}X_2 + \ldots + a_{ip}X_p$
2. The sum of squares of the component coefficients a_{ij}, $j=1 \ldots p$, is unity.

3. Of all possible combinations of this type, Y_1 (the first principal component) has the greatest variance (i.e. accounts for the greatest proportion of the total variance).
4. Of all possible combinations of this type not correlated with Y_1, Y_2 has the greatest variance; Y_3 has the greatest variance of combinations not correlated with Y_1 and Y_2, and so on until the complete set of principal components, from Y_1 to Y_p, has been defined.

The principal components so defined are not correlated with each other and are arranged in order of decreasing variance explained. Frequently, the first few principal components will account for a large proportion of the variability in the original data, and these few can then be used in further analyses, in place of the original variables, with minimal loss of information.

Interpretation of principal components is based on the loadings of each of the original variables on each of the principal components. These loadings are the correlations of the original variables with the principal components, which are generally more useful than the component coefficients for interpretive purposes (Johnson and Wichern 1982). Variables with high loadings on the same principal component tend to be highly correlated with each other, and each principal component is interpreted according to the magnitudes of the loadings associated with it. In some cases, the principal components clearly may represent some identifiable factors such as various environmental influences. Although this kind of interpretation usually is not possible for benthic invertebrates, each principal component of benthic invertebrate abundance data still may still be interpreted in terms of the abundances of the constitutent taxa.

For the purpose of interpreting principal components when the number of original variables is large, it is useful to consider only those variables with relatively large (absolute value) loadings on each principal component. Determination of what represents a large loading is arbitrary and will depend to some extent on the number of original variables and the sample size. When interpreting principal components in the present study, we have considered only loadings greater than 0.25 absolute value. This approach is used only for convenience of interpretation. Since principal component scores are calculated using all of the original variables, subsequent analyses based on these scores are not affected by the criteria used to select large loadings.

2.3.1.1 Water quality PCA. The determination of which water quality variables to include in a principal component analysis was based on several considerations. Since variables that are calculated from other variables (e.g., total hardness) are redundant, these were not included. In addition, variables that were almost always at or below the detection limit (e.g., carbonate) provided little information and these were also omitted from the analysis. PCA requires measurements of all variables for all samples. Not all variables were determined for every water sample, however, and some variables were measured infrequently. The selection of variables was necessarily, therefore, a compromise between the desire to include as many variables as possible and the desire to include as many water samples as possible.

After examining the number of samples included when several different subsets of water quality variables were selected, a set of 29 variables was chosen as representing a reasonable compromise in terms of maximizing both the number of variables and the number of samples. These 29 variables were subjected to a principal component analysis and 343 water samples were included. This selection procedure eliminated 195 samples, including all of those taken prior to 1978.

For the purpose of examining the relationships between water quality and benthic invertebrates, it was desirable to include all water samples taken during 1981 at locations where benthic invertebrates were also sampled. This required further reduction of the number of water quality variables to a set of 20. A second PCA therefore was performed using these 20 variables. This analysis included 435 water samples.

Preliminary examination of the distributions of values for each of the water quality variables suggested that a logarithmic transformation would be appropriate (to more closely approximate normality) for all variables except pH. A $\log_{10}$ transformation was therefore applied to all variables except pH prior to performing a PCA. Values that were recorded as being less than a detection limit were changed to a value slightly less than the detection limit before transforming to logarithms. For example, if the detection limit was 0.02, a value of 0.019 was assigned to measurements reported as less than that limit. This assignment of values was done by the Water Quality Control Branch before the data files were made available.

Principal components were derived from the correlation matrix of water quality variables and an orthogonal rotation of the loadings matrix was applied using the Varimax criterion (Harman 1976). The purpose of the rotation was to allow a simpler interpretation of the principal components. Components that accounted for more than 3% of the total variance were retained for subsequent analysis.

2.3.1.2 Benthic invertebrates PCA. Because the composition of benthic invertebrate communities changes substantially on a seasonal basis, it is preferable to apply the method of PCA to data collected over a relatively short period of time. Accordingly, four separate analyses were performed: one for each of the months of May, June, July, and August. Data from the two sampling periods in each of May, June, and July were pooled for these analyses. In August, data was available for only one sampling period.

Rare taxa usually provide little information and can sometimes create computational difficulties in PCA. Therefore, for each analysis, only those taxa comprising at least 10% of any one sample, or found in at least 10% of the samples, were included. Analyses were performed using taxon abundances (number/m^2) transformed to $\log_{10}$ (abundance +1). Principal components were derived from the covariance matrix of transformed abundances. This is the preferred method of PCA when all variables are measured in the same units

(Morrison 1976; Green 1979). Because orthogonal rotation of the loadings matrix did not yield a simpler interpretation of the principal components, the unrotated components were used. Principal components that accounted for more than 4% of the total variance were retained for subsequent analysis.

2.3.2 Other Statistical Procedures

Statistical comparisons of sampling stations, with respect to benthic invertebrates, were made using analysis of variance and Student-Newman-Keuls (S-N-K) multiple comparisons procedures (Sokal and Rohlf 1969; Winer 1971). These comparisons were based on the principal components of taxon abundances. A one-way analysis of variance was first used to test each principal component for any differences among stations. For any principal component that showed a significant difference among stations, all pairwise comparisons of stations were then made using the S-N-K multiple comparisons method.

The relationships between water quality and benthic invertebrates were examined using simple correlation analysis, based on correlations among principal components. The Pearson product-moment correlation coefficient (Sokal and Rohlf 1969) was computed for each benthic invertebrate principal component paired with each water quality principal component, and tested for significance. Examination of scattergrams gave no indication that any relationship other than linear would be appropriate for any pair of components.

Correlation analyses, analysis of variance, and S-N-K multiple comparisons tests all were performed using computer programs of the Statistical Package for the Social Sciences (Nie et al. 1975).

3. RESULTS AND DISCUSSION

3.1 WATER QUALITY

3.1.1 Water Quality, 1976 to 1983

For reasons outlined earlier (Section 2.3.1.1), it was not possible to include all 68 water quality variables in a principal component analysis. The data for all variables are, however, presented for reference purposes in Figures 16 to 83 (Appendix 7.1). There is one figure for each variable, and each figure includes data for the seven sampling stations, covering the period 1976 to 1983.

The results of principal component analysis of 29 selected water quality variables are presented in Table 1, which contains the principal component loadings for each water quality variable. Eight principal components (PCs) accounted for 78% of the total variance. PC1 accounted for 36.4% and PC2 accounted for 17.0% of the total variance while the amount of variance explained by each of PCs 3, 4, 5, 6, 7, and 8 was 5.8%, 5.1%, 4.0%, 3.7%, 3.3%, and 3.2%, respectively. The scores for a PC, which are computed for each water sample, are determined primarily by the variables having the largest loadings (absolute value) on that PC.

The first principal component (PC1) has high loadings for specific conductance, total alkalinity, filterable residue, and all the major ions (although the loading for potassium is relatively low). Nitrate and nitrite nitrogen and ammonia also are associated with this PC, as is iron. Non-filterable residue and total organic carbon are inversely related to this component (indicated by the negative signs of the loadings). PC1 clearly represents primarily dissolved solids, in a general way.

PC2 represents non-filterable residue, total organic carbon, total phosphate, and all the metals except mercury. The loading for lead is relatively low, however. Ammonia is also associated with this component to some degree, as are sodium and chloride, the latter two in a negative manner. A strong association between non-filterable residue, total phosphate, and most of the metals is indicated.

Table 1. Principal component loadings for the first eight principal components of 29 water quality variables. Loadings greater than 0.25 absolute value are printed in boldface.

Variable	NAQUADAT Code	Principal Component Loadings							
		PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
PH	10301L	0.124	-0.119	**-0.586**	**-0.451**	0.161	-0.181	0.075	-0.101
Specific Conductance	02041L	**0.908**	-0.246	0.248	0.026	0.042	0.043	0.015	-0.023
Calcium	20103L	**0.937**	-0.055	-0.135	0.042	0.051	-0.124	-0.017	0.051
Magnesium	12102L	**0.940**	-0.222	-0.017	0.110	0.036	0.013	-0.008	-0.001
Potassium	19102E	**0.263**	0.099	-0.034	**0.771**	0.193	0.018	0.068	0.047
Sodium	11102L	**0.737**	**-0.289**	**0.527**	0.016	0.075	0.064	0.074	-0.001
Chloride	17203L	**0.570**	**-0.338**	**0.644**	-0.055	0.086	-0.010	0.093	-0.027
Sulphate	16306L	**0.920**	-0.157	-0.069	0.119	0.007	0.084	-0.000	-0.058
Total Alkalinity	10101L	**0.967**	-0.080	-0.049	0.087	0.065	-0.064	-0.034	0.049
Bicarbonate	06201L	**0.967**	-0.078	-0.048	0.088	0.065	-0.063	-0.034	0.051
Filterable Residue	10451L	**0.931**	-0.178	0.196	0.096	0.093	0.026	0.010	0.031
Non-filterable Residue	10401L	**-0.590**	**0.606**	-0.240	-0.145	-0.181	0.161	-0.066	0.058
Total Organic Carbon	06001L	**-0.271**	**0.451**	-0.076	-0.016	0.011	**0.300**	0.070	0.222
Nitrate + Nitrite N	07110L	**0.734**	0.105	**0.348**	-0.142	-0.034	0.221	-0.027	0.121
Ammonia N	07555L	**0.342**	**0.324**	**0.323**	-0.119	-0.041	-0.198	-0.174	0.162
Total Phosphate P	15406L	-0.203	**0.835**	-0.054	-0.171	-0.120	0.153	0.029	0.036
Dissolved Orthophosphate P	15256L	0.081	0.117	0.088	0.082	-0.107	**0.865**	-0.025	0.060
Phenolic Material	06532L	0.122	-0.036	0.065	-0.014	-0.045	0.066	0.099	**0.882**
Oil and Grease	06521L	-0.021	0.220	-0.015	0.103	**0.465**	-0.208	**-0.444**	**0.318**
Cyanide	06603L	-0.153	0.049	0.005	-0.014	**-0.701**	0.191	0.001	0.011
Iron	26304L	**-0.391**	**0.821**	-0.111	-0.142	-0.108	0.079	-0.008	0.117
Manganese	25304L	-0.246	**0.905**	-0.044	-0.095	-0.054	0.002	-0.033	0.020
Copper	29305L	-0.030	**0.777**	0.012	0.044	0.162	0.051	0.100	-0.089
Zinc	30305L	-0.041	**0.782**	0.012	0.160	**0.274**	0.070	-0.008	0.015
Lead	82302L	0.058	**0.292**	-0.047	0.021	**0.612**	**0.384**	0.035	-0.147
Mercury	80015L	-0.025	0.099	-0.015	0.028	0.015	-0.050	**0.902**	0.142
Arsenic	33104L	0.000	**0.850**	0.104	0.128	0.026	-0.093	-0.074	-0.063
Vanadium	23002L	-0.103	**0.441**	-0.151	**-0.616**	0.148	-0.066	0.070	0.141
Nickel	28302L	-0.080	**0.902**	-0.016	-0.051	0.066	0.011	0.014	-0.018

The third PC is primarily a measure of sodium and chloride that is independent of PC1 (and therefore of the other major ions). Ammonia and nitrate plus nitrite nitrogen are also associated with PC3 to some degree, and pH is inversely related to it. It will become clear later that PC3 represents primarily the higher sodium and chloride levels of the Clearwater River and, possibly, other right bank tributary streams.

Potassium is the only variable with a large positive loading on PC4. Vanadium and pH are inversely related to this PC. The high loading for potassium on PC4 indicates that the concentration of potassium is largely independent of the concentrations of the other major ions.

PC5 has high loadings for oil and grease, lead, and zinc, indicating an association between oil and grease and at least some forms of lead and, to a lesser extent, zinc. Cyanide has a strong negative correlation with PC5, and this is the only PC with which cyanide is strongly associated.

Dissolved orthophosphate loads heavily on PC6 and total organic carbon and lead also are associated with this component, but to a lower degree. PC6 therefore represents primarily orthophosphate and is the only PC with which orthophosphate is strongly associated.

PC7 represents primarily mercury, and the loading for oil and grease on this PC indicates a negative correlation between mercury and oil and grease.

Phenolic material and oil and grease are the only variables associated strongly with PC8. This component is therefore primarily a measure of these two variables.

Plots of the eight principal components are presented in Figures 2 to 9 for all seven water quality monitoring stations during the period 1978 to 1983. All samples taken prior to 1978 were omitted from this analysis because they lacked measurements for one or more of the water quality variables.

As would be expected, PC1 (representing dissolved solids) shows marked seasonal fluctuations with the highest values occurring during the winter months. Differences between left and right bank samples were not large in most instances. Values of PC1 were consistently higher, however, for left bank samples at Station DA0205 (below the Suncor effluent outfall) in 1982 and 1983, particularly during winter. Station DA0203 also had higher values of PC1 in left bank samples, at least during winter, and the difference may therefore reflect only differences between the Athabasca and Clearwater rivers rather than an effect of the Suncor effluent. In general, there were no substantial differences between any of the stations with respect to PC1.

The highest values for PC2, which represents non-filterable residue, total organic carbon, total phosphate, and several metals, occurred during the spring and summer months and were presumably related to high discharges. There was no evidence of consistent differences between left and right bank samples at any station, and the values at all stations were usually similar.

PC3, primarily a measure of sodium and chloride, showed much higher values in right bank samples than in left bank samples at both stations DA0203 and DA0205, and clearly reflects the influence of the Clearwater River, which has higher sodium and chloride concentrations than the Athabasca River (Akena 1982). At stations DA0206 and DA0207, right bank samples frequently had higher PC3 values than left bank samples, but the differences were not as great or as consistent as at stations DA0203 and DA0205. The differences observed at stations DA0206 and DA0207 may be the result of influences of right bank tributary streams other than the Clearwater River, or of saline groundwater sources. Mixing of the Athabasca River is reported to occur at a sharp bend in the river of the Suncor dyke (Boerger 1983). The large differences observed at Station DA0205 suggest, however, that mixing may not be complete at this point, which is a short distance downstream from the dyke. The highest values for PC3 most often occurred in the first months of the year, but seasonal fluctuations were not as regular as was the case with PC1.

PC4, which is related primarily to potassium (directly) and vanadium (inversely), did not show large or consistent differences between left and right bank samples at any station, and values did

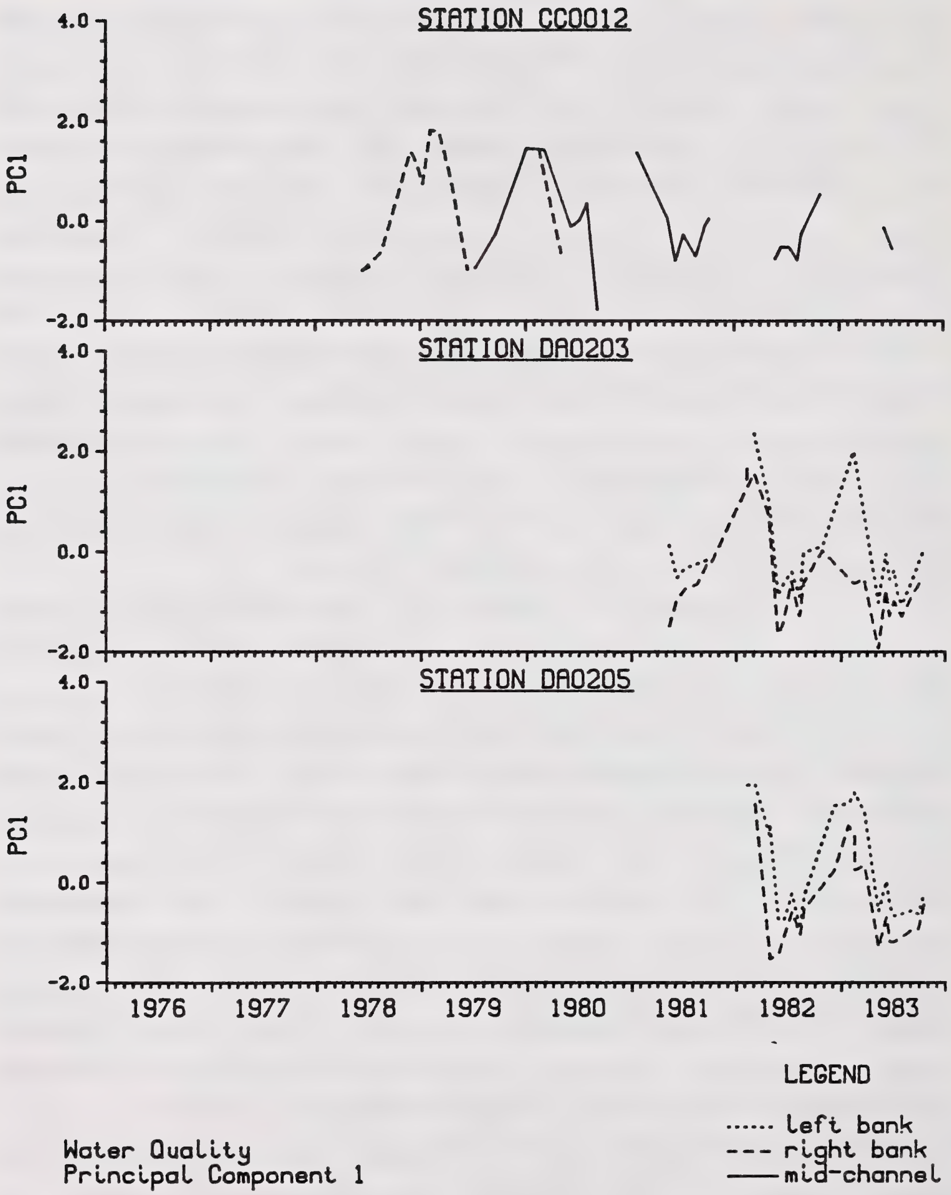

Figure 2. Principal component scores for water quality PC1 at seven stations on the Athabasca River.

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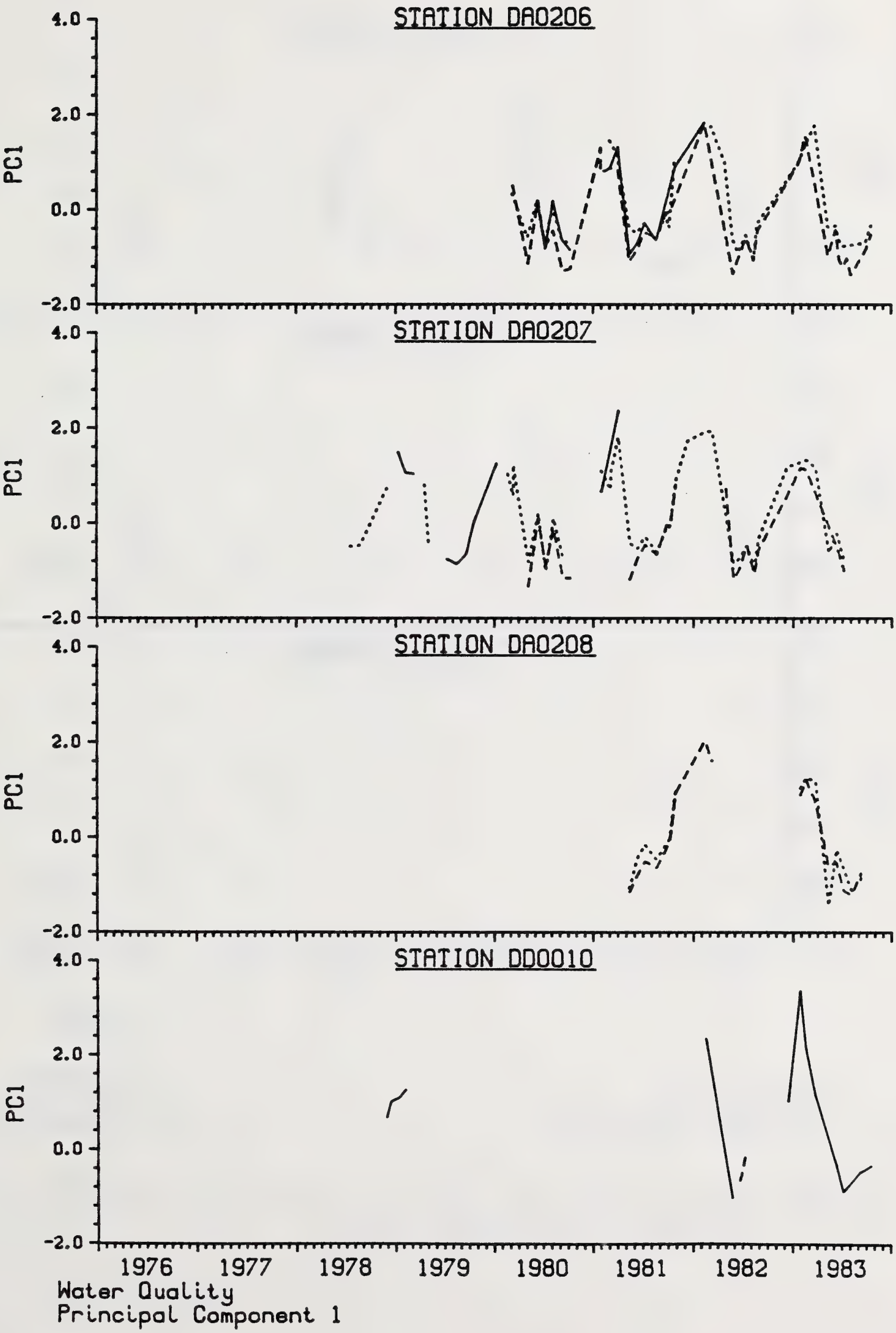

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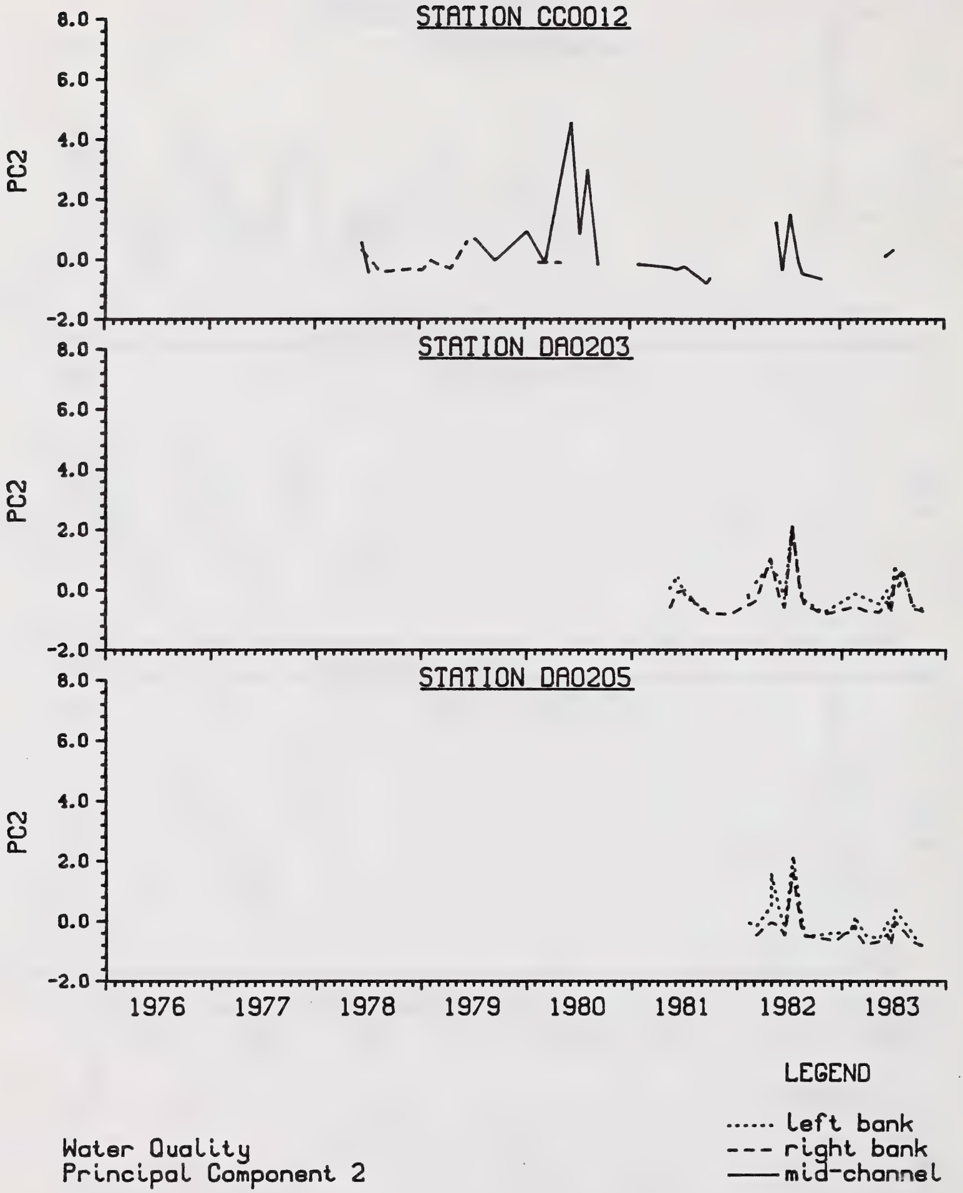

Figure 3. Principal component scores for water quality PC2 at seven stations on the Athabasca River.

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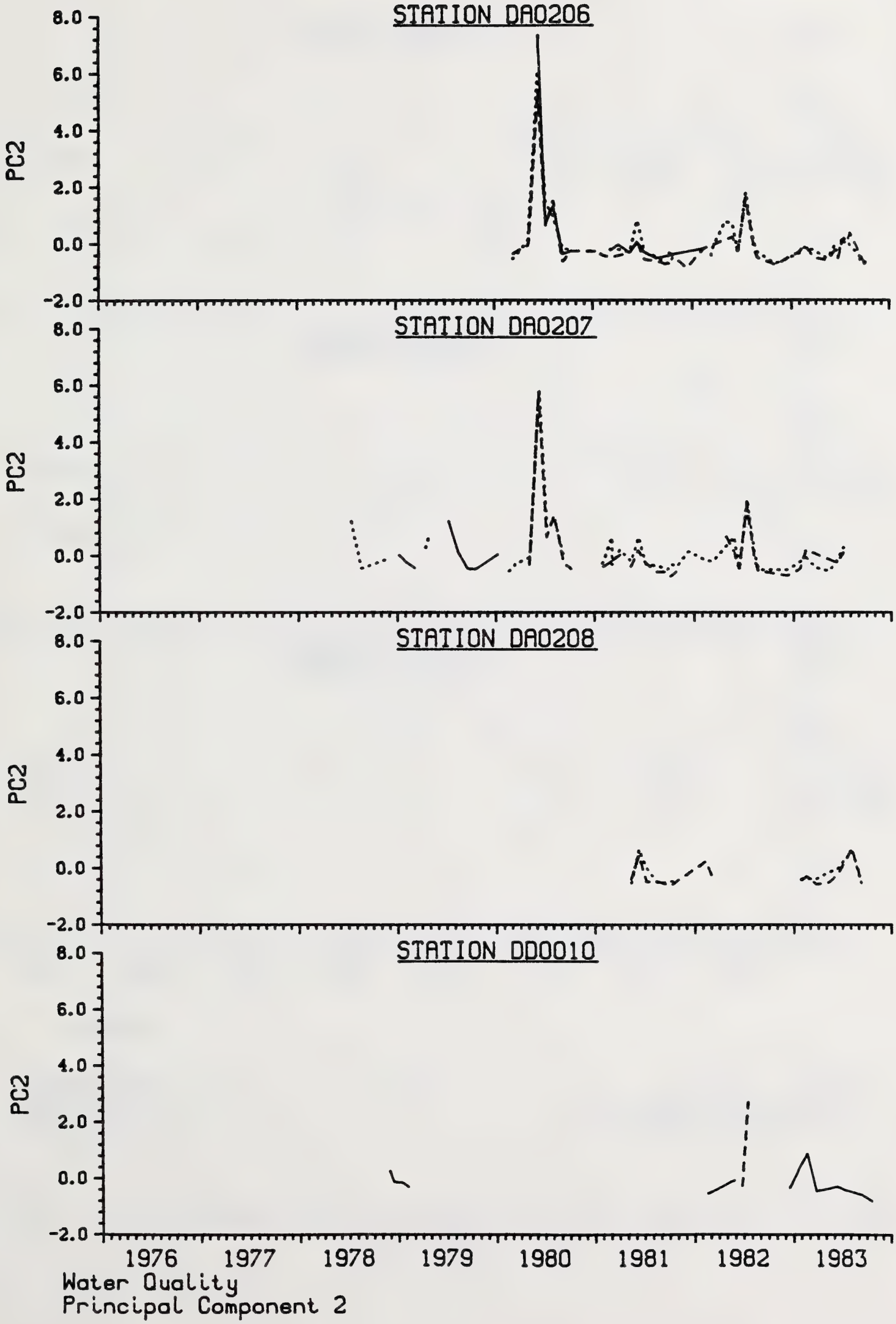

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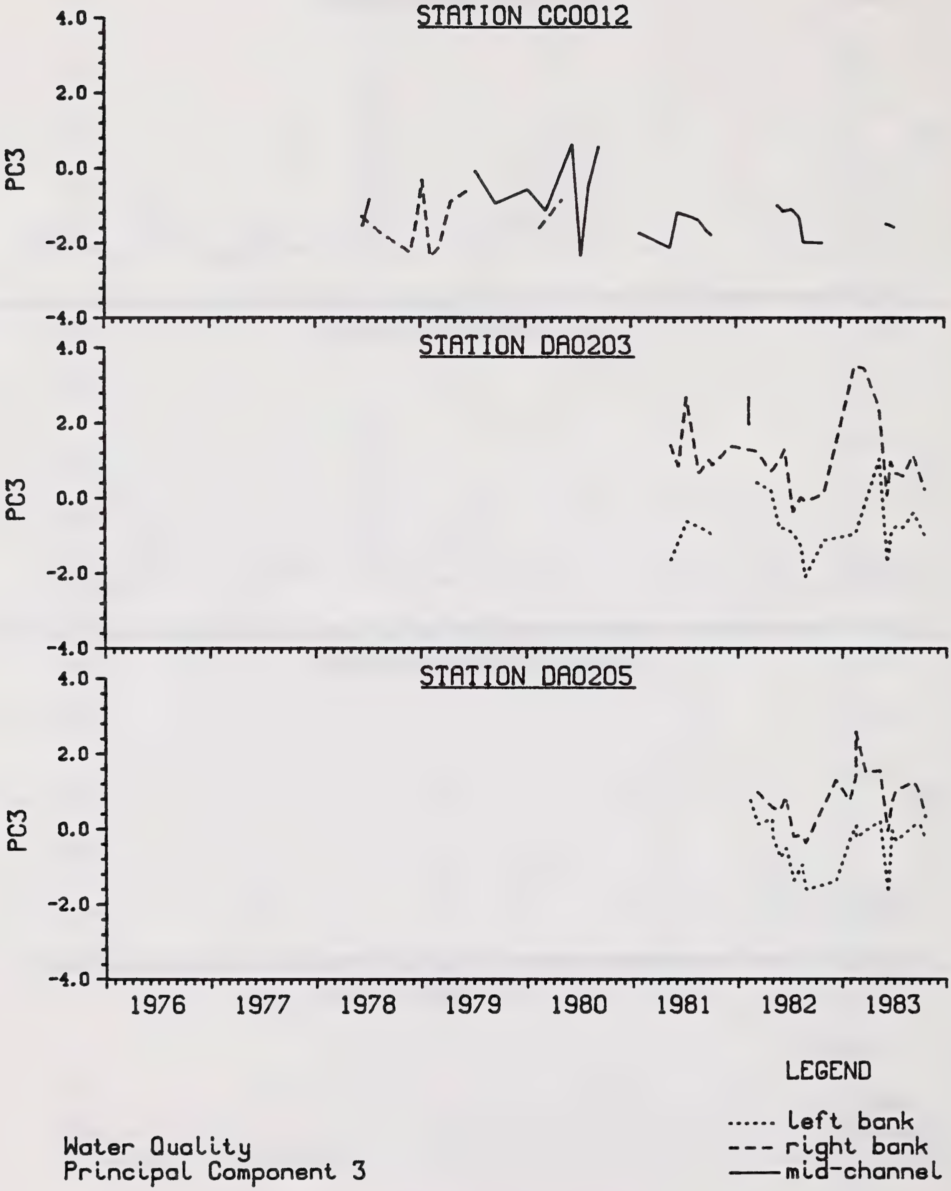

Figure 4. Principal component scores for water quality PC3 at seven stations on the Athabasca River.

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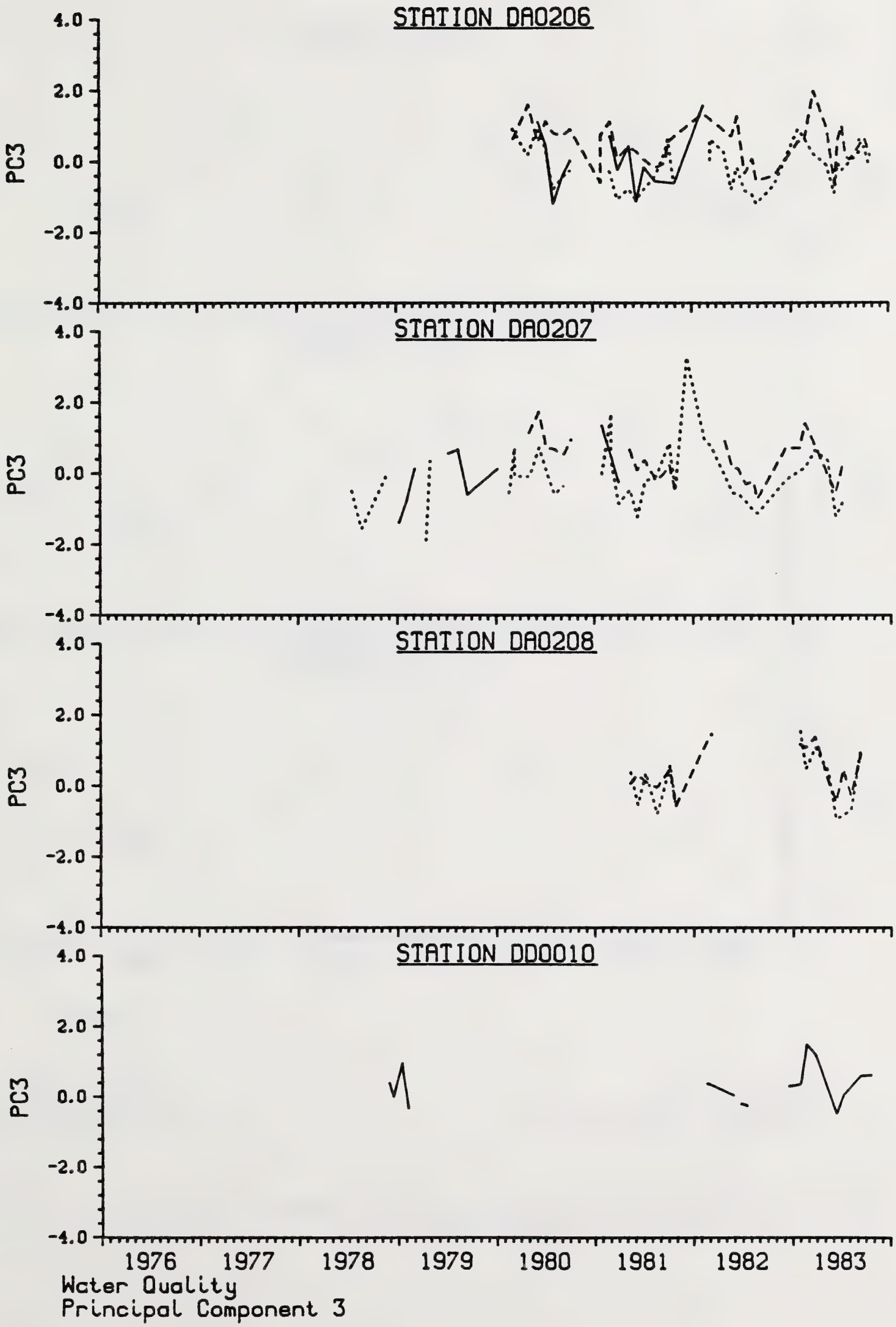

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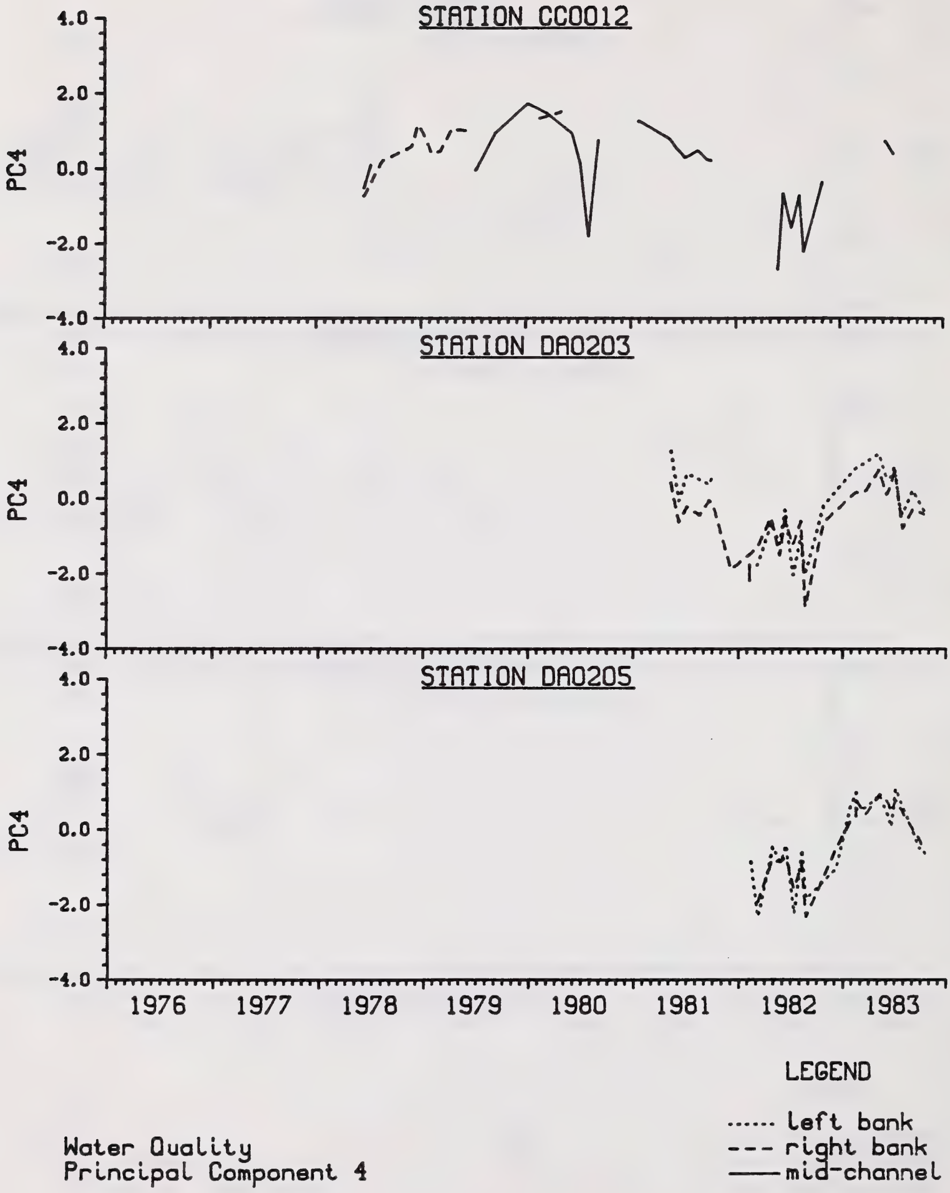

Figure 5. Principal component scores for water quality PC4 at seven stations on the Athabasca River.

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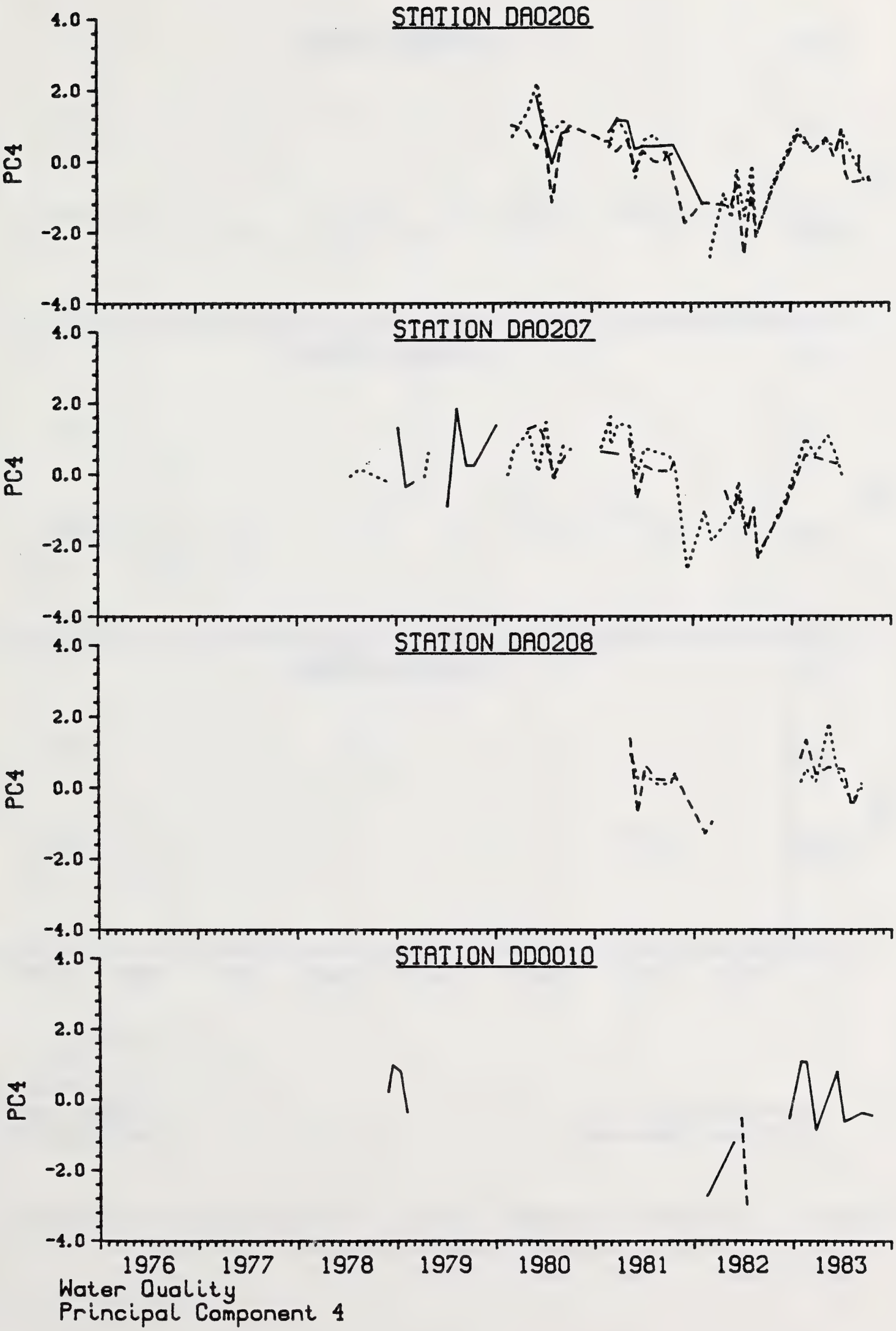

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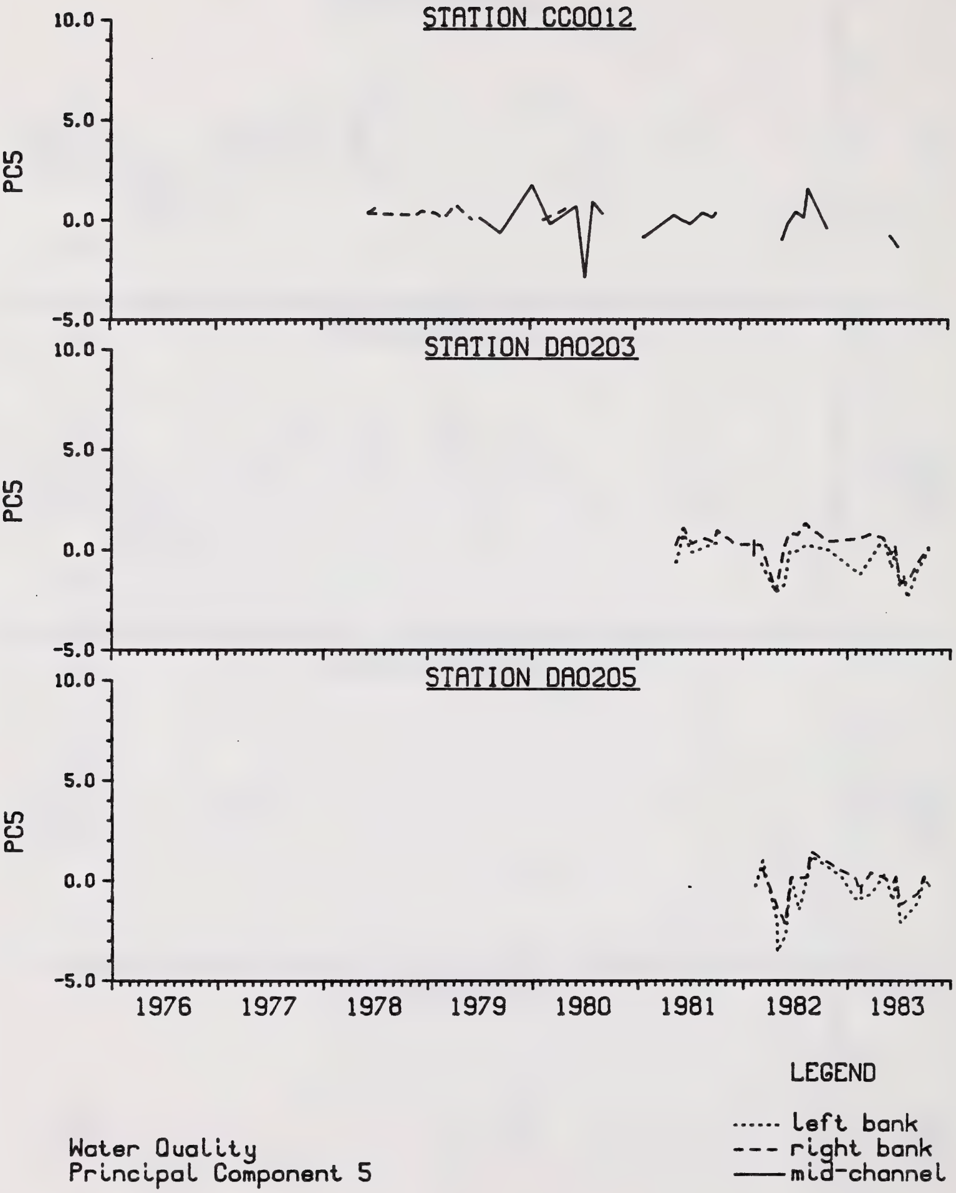

Figure 6. Principal component scores for water quality PC5 at seven stations on the Athabasca River.

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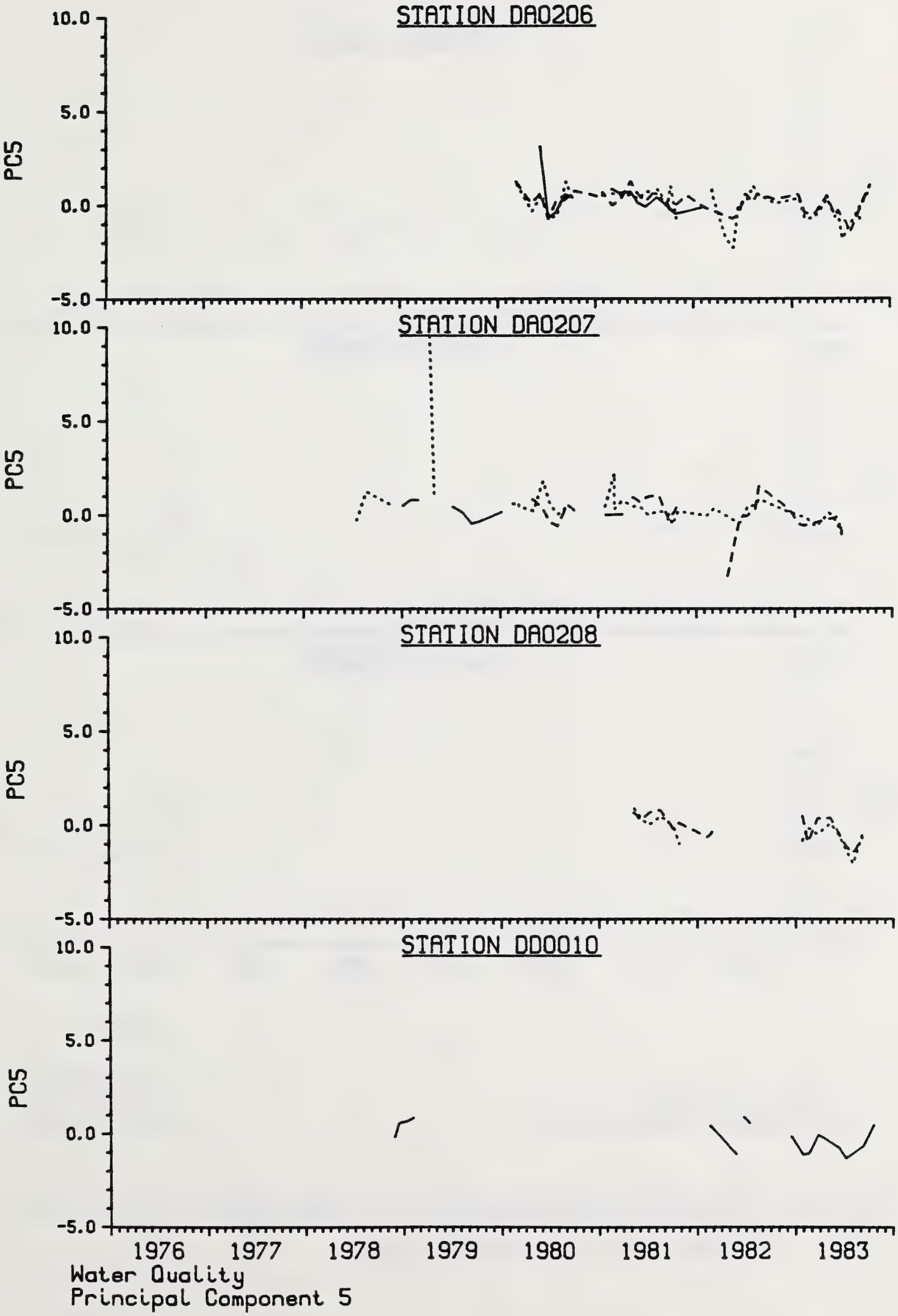

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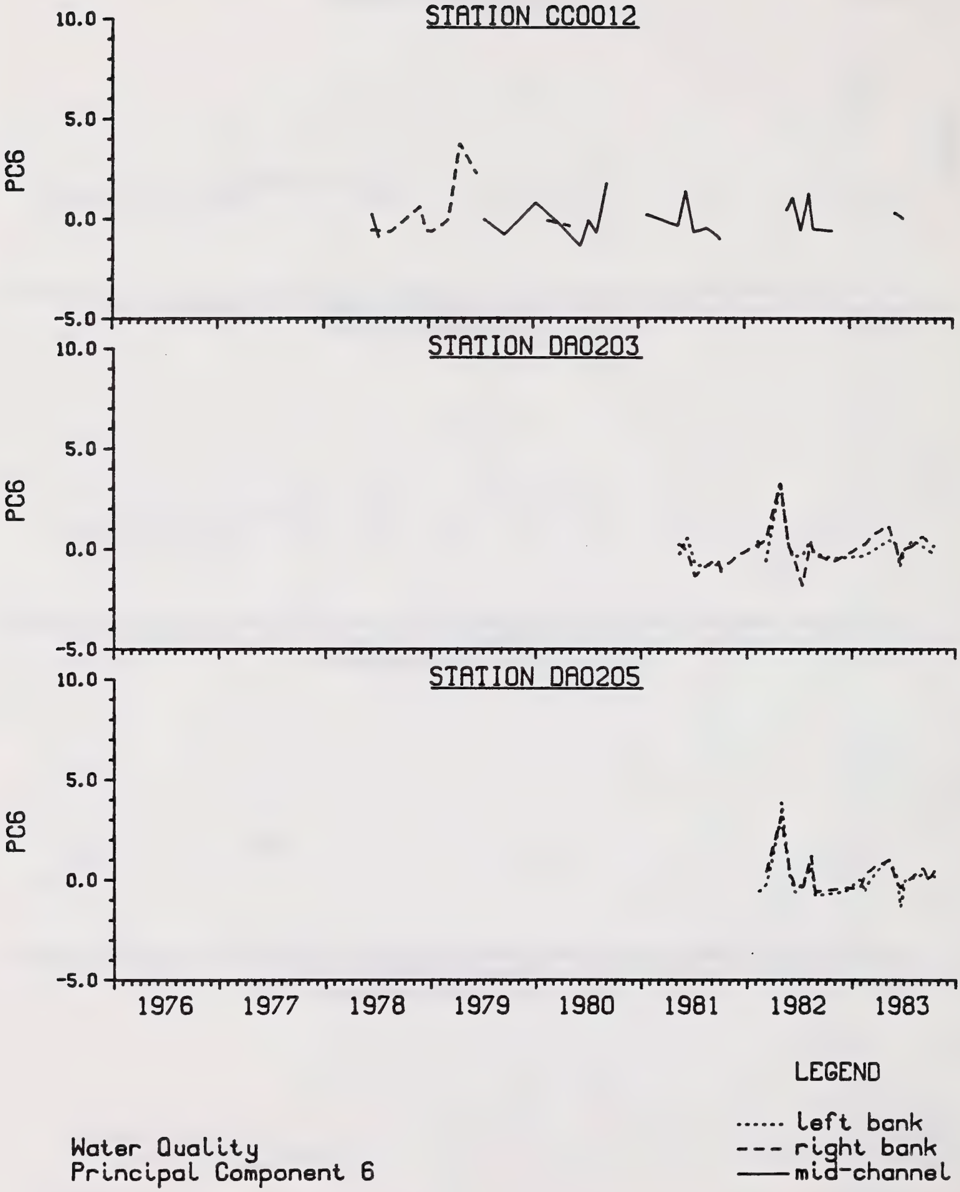

Figure 7. Principal component scores for water quality PC6 at seven stations on the Athabasca River.

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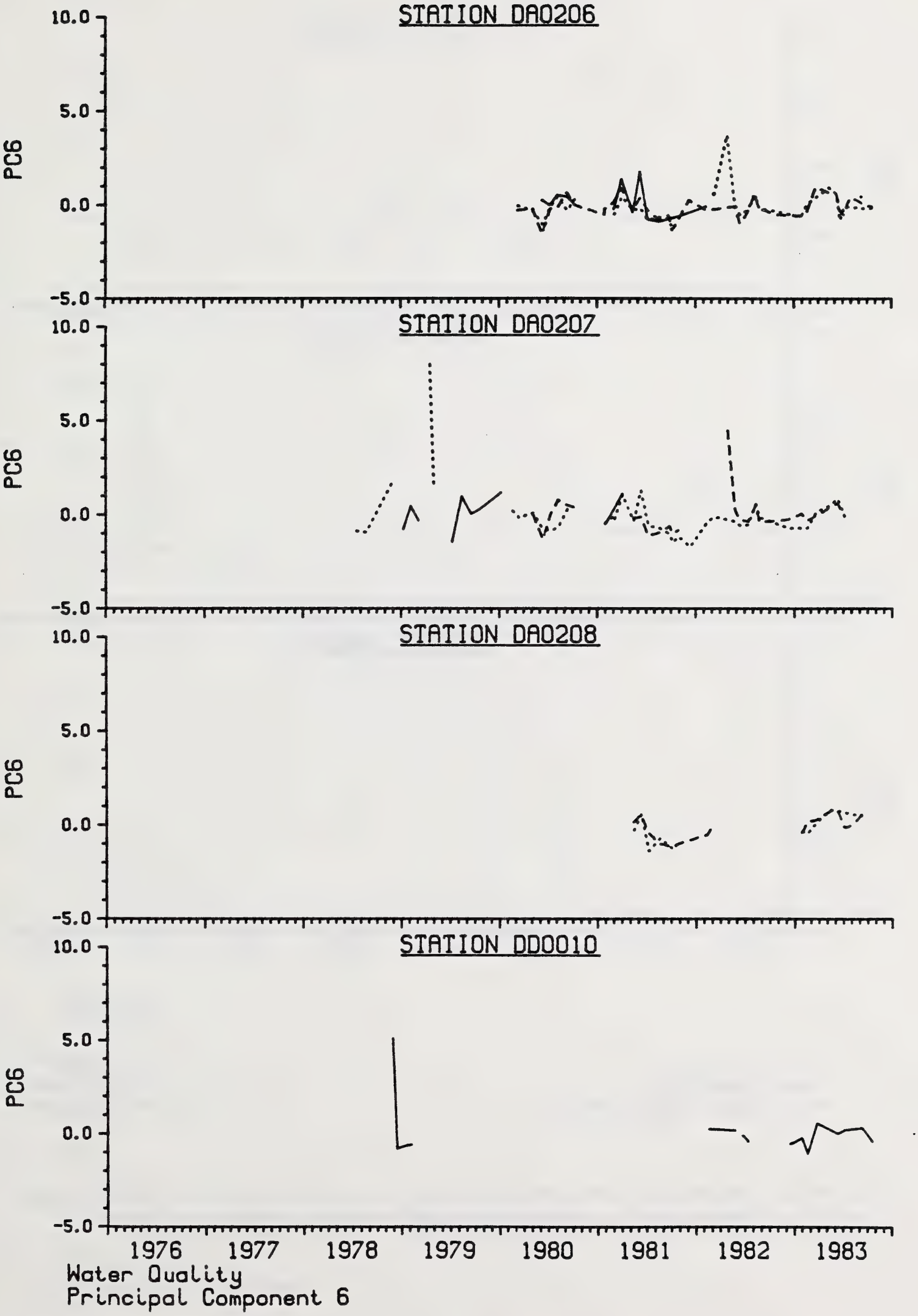

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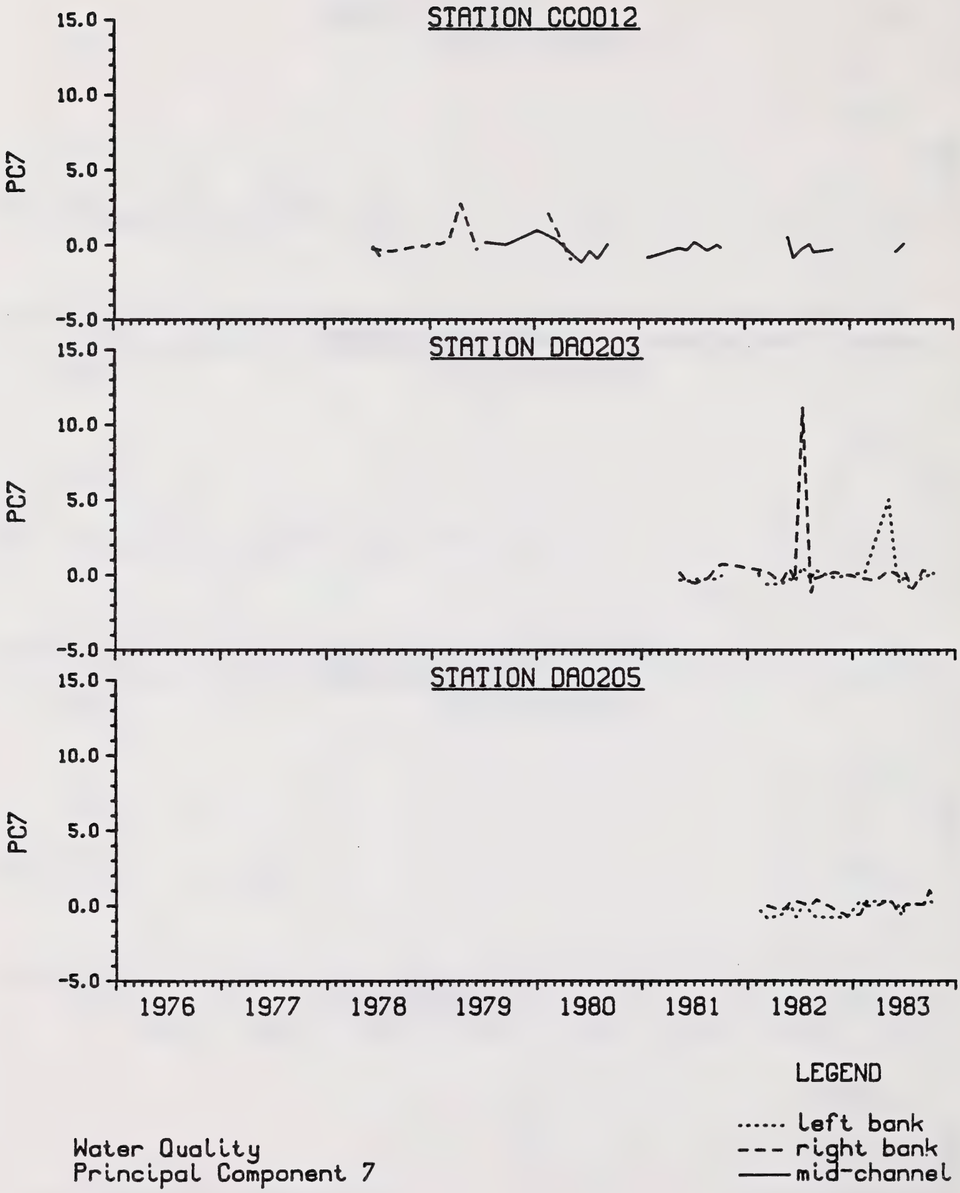

Figure 8. Principal component scores for water quality PC7 at seven stations on the Athabasca River.

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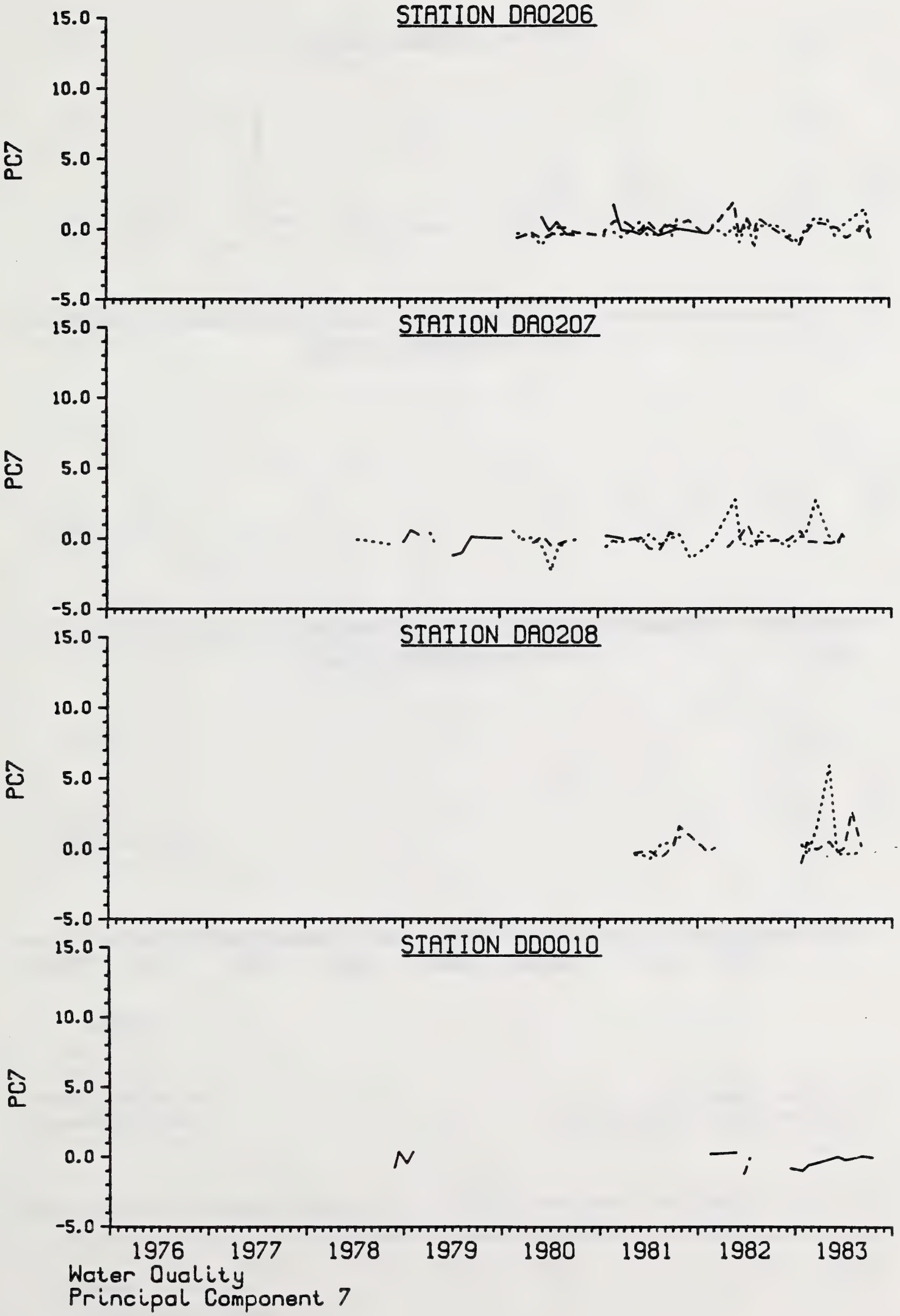

Figure 8. Concluded.

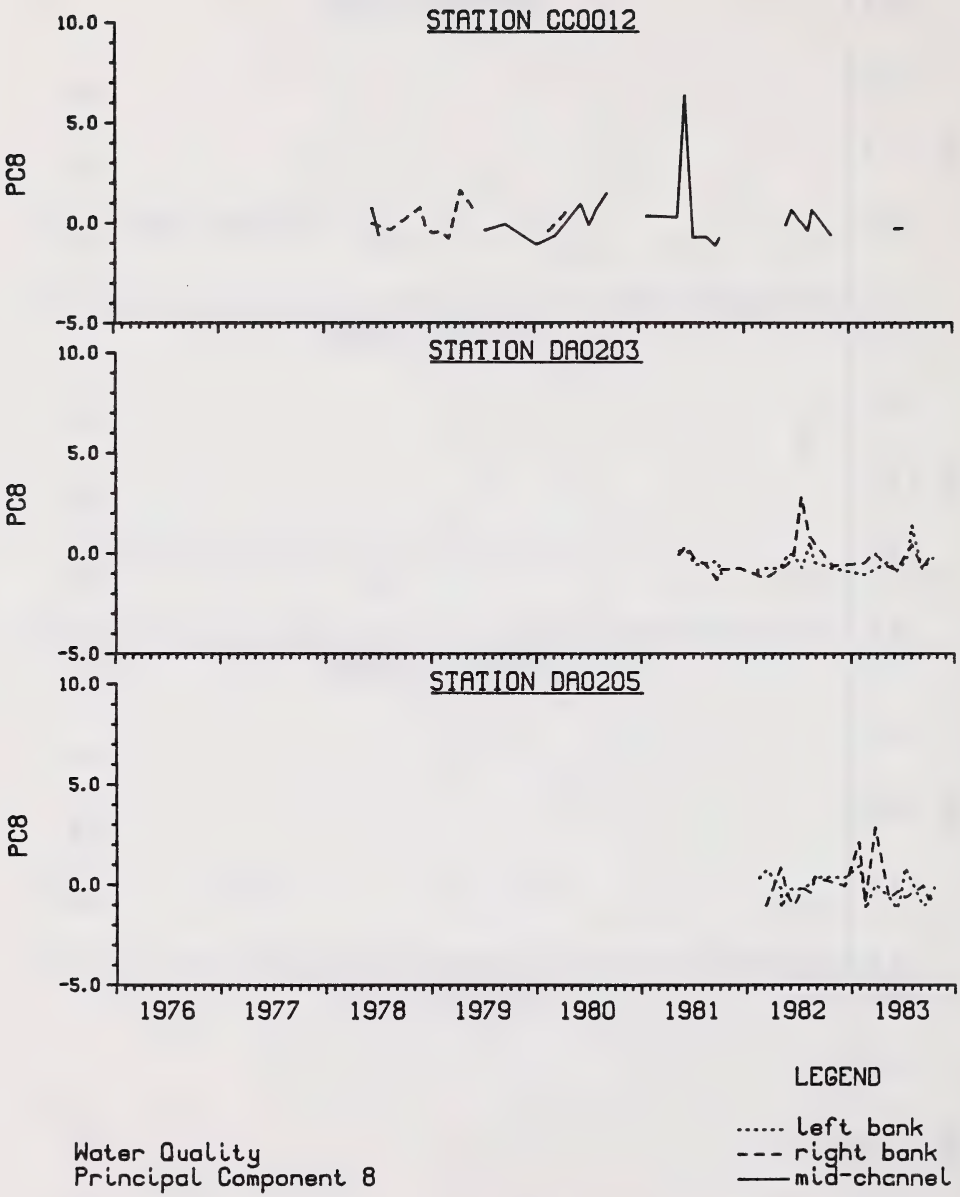

Figure 9. Principal component scores for water quality PC8 at seven stations on the Athabasca River.

continued . . .

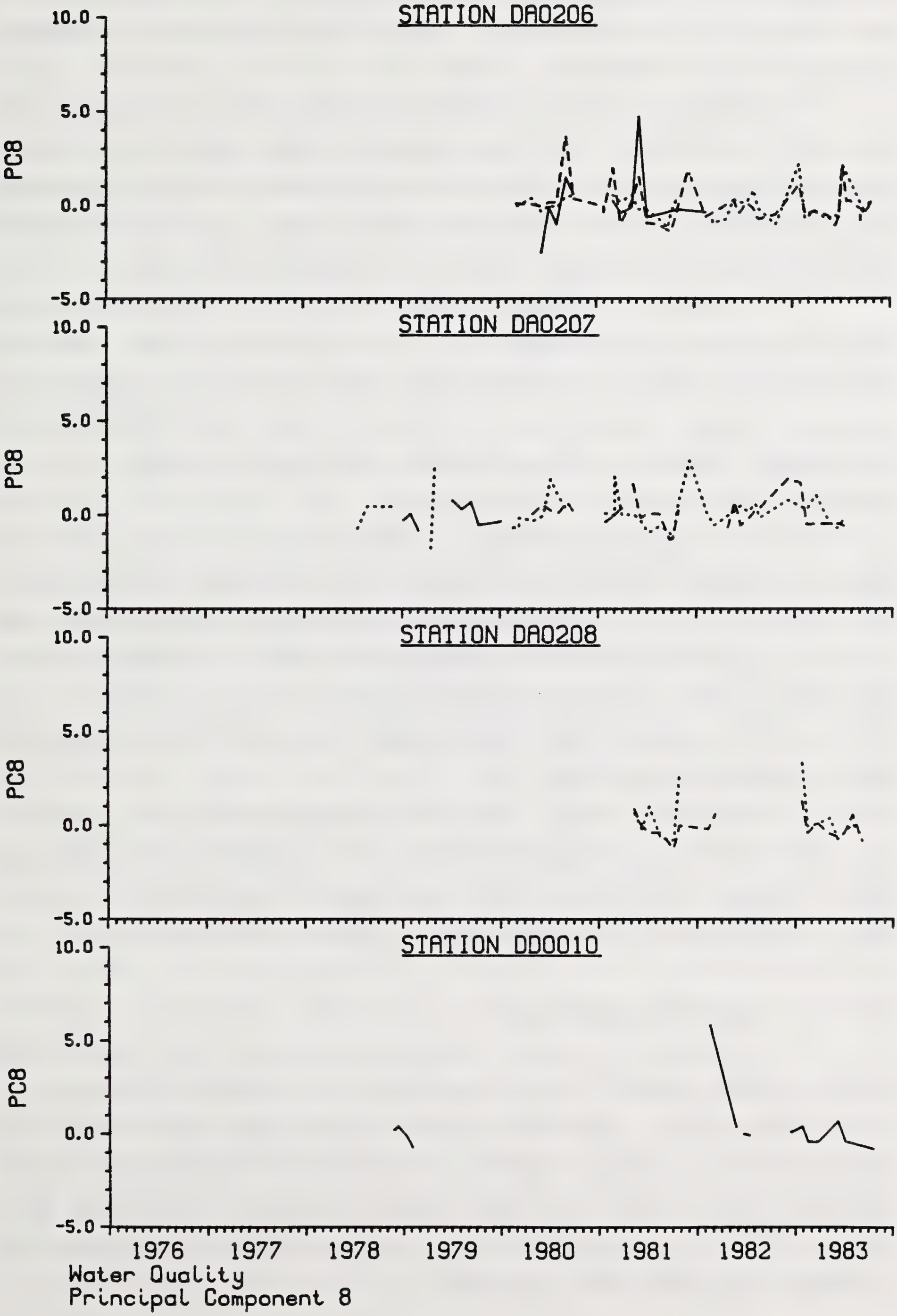

Figure 9. Concluded.

not appear to differ markedly between stations. Although changes in PC4 during the year were evident, these changes were not consistently related to season from year to year.

Values for PC5 (representing lead, oil and grease, and zinc on the positive side, and cyanide on the negative side) were generally similar at all stations, and there was no clear indication of any consistent differences between left and right bank samples. Fluctuations of PC5 did not appear to be seasonal in nature.

Although the highest values for PC6, which represents primarily dissolved orthophosphate and, to a lesser extent, lead and total organic carbon, tended to occur in early spring, the pattern of seasonal changes was not very regular. There was no evidence of differences between stations, and PC6 was usually similar for left and right bank samples at all stations.

PC7, which represents primarily mercury, did not show regular seasonal changes and, except for occasional peaks, values were similar at all stations and in left and right bank samples. Two of the largest values for PC7 occurred at Station DA0203; one in a right bank sample in mid-1982, and one in a left bank sample in May of 1983. A similar peak was observed in a left bank sample at Station DA0208 in May 1983.

Fluctuations of PC8 (representing primarily phenolic material and oil and grease) did not show a consistent seasonal pattern. Values for left and right bank samples were usually similar, and no consistent differences between stations were apparent.

3.1.2 Water Quality, 1981

In order to assess relationships between water quality and benthic invertebrates, it was desirable to include in analyses all water samples taken in 1981 at locations and times corresponding to the benthic invertebrate sampling program. For this purpose, it was necessary to restrict the water quality variables considered to a group of 20. A second principal component analysis therefore was performed using these 20 variables.

Results of a principal component analysis of the selected variables are presented in Table 2, which contains the principal component loadings for each water quality variable. The PC scores for each sample are determined primarily by the variables having the largest (i.e., at least 0.25 absolute value) loadings on each PC. Six principal components accounted for 77% of the total variance and, for the most part, results were consistent with the results of the principal component analysis of 29 water quality variables presented in Section 3.1.1. PC1 accounted for 39.5% and PC2 accounted for 16.6% of the total variance. The percentage of the variance explained by each of PC3, PC4, PC5, and PC6 was 6.3%, 5.7%, 4.6%, and 4.3%, respectively.

The first principal component (PC1) has high loadings for specific conductance, total alkalinity, filterable residue, calcium, magnesium, sodium, and chloride. Nitrate plus nitrite nitrogen is also associated with this PC, and non-filterable residue and total organic carbon are negatively correlated with it. In general, PC1 can be considered to represent primarily dissolved solids.

PC2 represents non-filterable residue, total phosphate, total organic carbon, and several metals (manganese, copper, zinc, and vanadium). Sodium and chloride have an inverse relationship with this PC. The loadings for PC2 indicate a strong relationship between non-filterable residue, total phosphate, and most of the metals.

The third PC represents primarily potassium, copper, zinc, and lead. The large loading for potassium on PC3 and the relatively low loading for potassium on PC1 indicate that the concentration of potassium is largely independent of the concentrations of the other major ions.

PC4 has high loadings for sodium, chloride, ammonia, and to a lesser extent, nitrate plus nitrite nitrogen. This component is primarily a measure of sodium and chloride (that is independent of PC1) and ammonia. As was the case with the third principal component in the analysis of Section 3.1.1, PC4 reflects the influence of the Clearwater River and, possibly, other right bank tributary streams.

Table 2. Principal component loadings for the first six principal components of 20 water quality variables. Loadings greater than 0.25 absolute value are indicated in boldface.

Variable	NAQUADAT Code	Principal Component Loadings PC 1	PC2	PC3	PC4	PC5	PC6
Specific Conductance	02041L	**0.923**	-0.246	-0.012	0.181	0.044	0.022
Calcium	20103L	**0.935**	-0.021	0.076	-0.063	-0.104	0.034
Magnesium	12102L	**0.931**	-0.218	0.055	0.020	0.022	0.005
Potassium	19102E	0.248	-0.208	**0.662**	0.008	**0.273**	0.007
Sodium	11102L	**0.732**	**-0.361**	0.014	**0.454**	0.128	0.052
Chloride	17203L	**0.580**	**-0.409**	-0.054	**0.527**	0.065	0.034
Total Alkalinity	10101L	**0.959**	-0.075	0.081	-0.015	-0.040	0.033
Filterable Residue	10451L	**0.910**	-0.246	0.067	0.167	0.045	0.041
Non-filterable Residue	10401L	**-0.630**	**0.638**	-0.012	-0.099	0.064	-0.029
Total Organic Carbon	06001L	**-0.318**	**0.393**	0.169	0.205	**0.368**	0.085
Nitrate + Nitrite N	07110L	**0.719**	0.155	0.004	**0.351**	0.171	0.132
Ammonia N	07555L	0.207	0.229	0.057	**0.723**	-0.071	0.022
Total Phosphate P	15406L	-0.219	**0.841**	0.100	0.056	0.235	-0.013
Dissolved Orthophosphate P	15256L	0.113	0.078	0.003	-0.060	**0.903**	-0.001
Phenolic Material	06532L	0.117	0.021	-0.005	0.041	0.014	**0.982**
Manganese	25304L	**-0.281**	**0.832**	0.193	0.099	0.072	-0.032
Copper	29305L	-0.051	**0.597**	**0.471**	0.090	0.083	-0.059
Zinc	30305L	-0.066	**0.587**	**0.570**	0.077	0.031	-0.034
Lead	82302L	0.037	0.194	**0.680**	-0.004	-0.137	0.014
Vanadium	23002L	-0.014	**0.710**	-0.182	-0.036	-0.189	0.114

The variable loading most heavily on PC5 is dissolved orthophosphate, and this is the only PC with which orthophosphate is strongly associated. Total organic carbon and potassium also are associated with PC5 to some degree, but their loadings are much smaller than the loading for orthophosphate. PC5 may therefore be considered to be primarily a measure of dissolved orthophosphate.

Phenolic material has a very high loading on PC6, and the loadings for all other variables on this component are very low. PC6 therefore essentially represents only phenolic material.

Plots of the six principal components for water samples taken during 1981 are presented in Figures 10 to 15. The PC scores presented are for water quality monitoring stations CC0012, DA0203, DA0206, DA0207, and DA0208, which correspond to benthic invertebrate sampling stations 8, 6, 3, 2, and 1, respectively.

Values of PC1, which represents primarily dissolved solids, declined from highs in February and March to lows during the spring and summer months, and then began increasing from September on. In general, PC1 did not differ markedly between stations, but some differences between left and right bank samples were apparent. At Station DA0203, PC1 scores were higher for left bank samples from May until late August, with the exception of one sample taken in late June. Similar differences were also evident at stations DA0206 and DA0207 until late August, again with the exception of one sampling date in June. These differences probably reflect the influence of the Clearwater River and other right bank tributaries. They do not appear to be related to sources of effluents.

The highest values for PC2 (representing primarily non-filterable residue, total phosphate, and several metals) occurred during the spring and summer months and were undoubtedly associated with periods of high discharge. In general, differences between stations were not large or consistent. There were some differences between left and right bank samples, however. Except on one date in June, PC2 scores were consistently higher for left bank samples at Station DA0203. At Station DA0206, PC2 was higher for left bank samples on all dates except during the period from late August to early

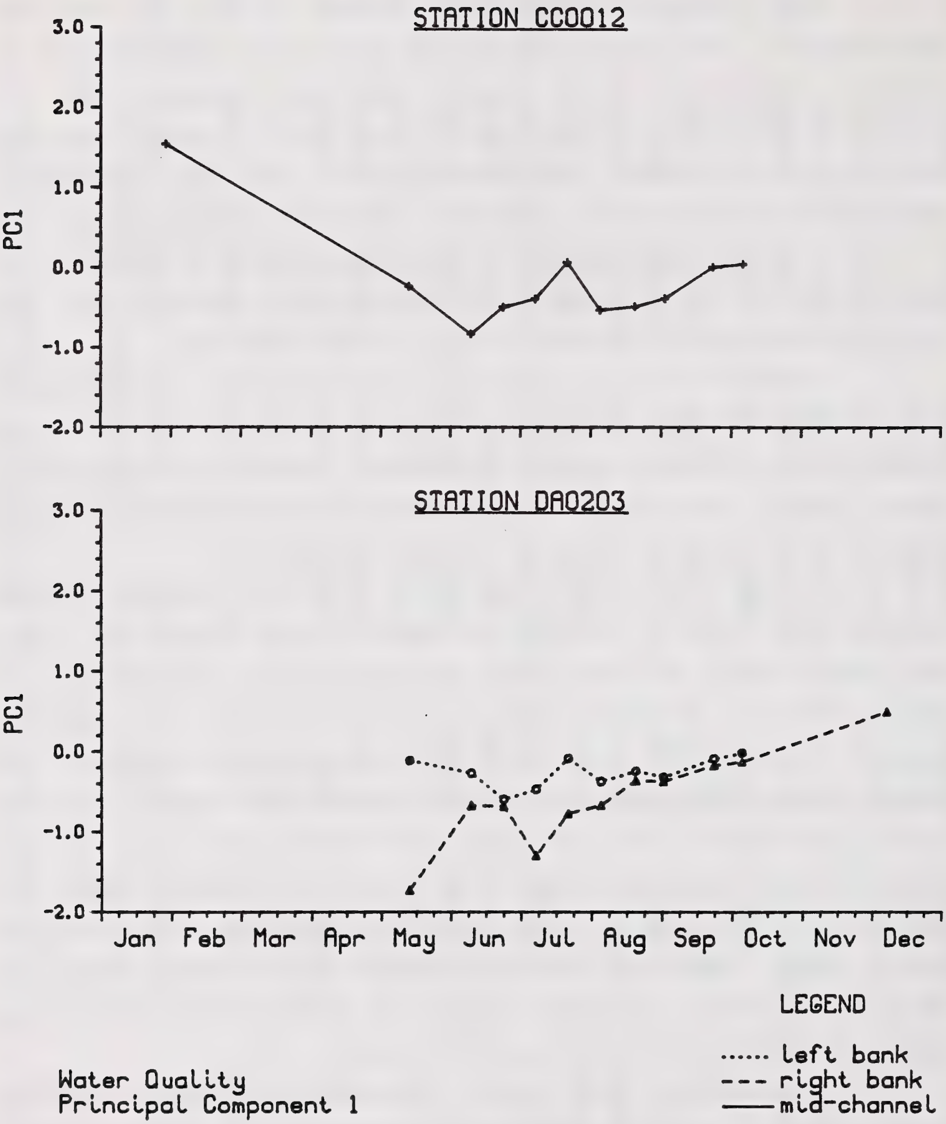

Figure 10. Principal component scores for water quality PC1 at five stations on the Athabasca River during 1981.

continued . . .

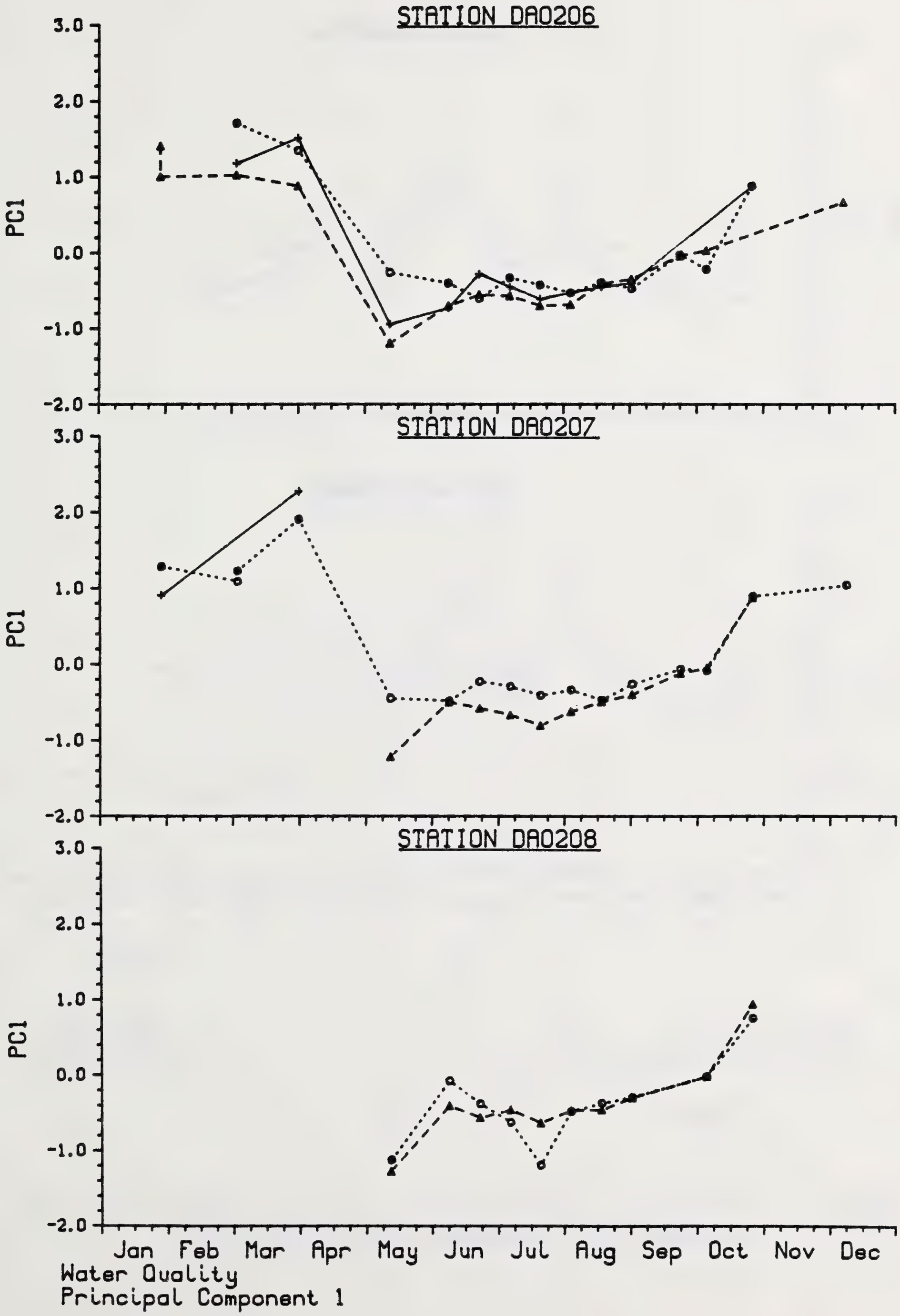

Figure 10. Concluded.

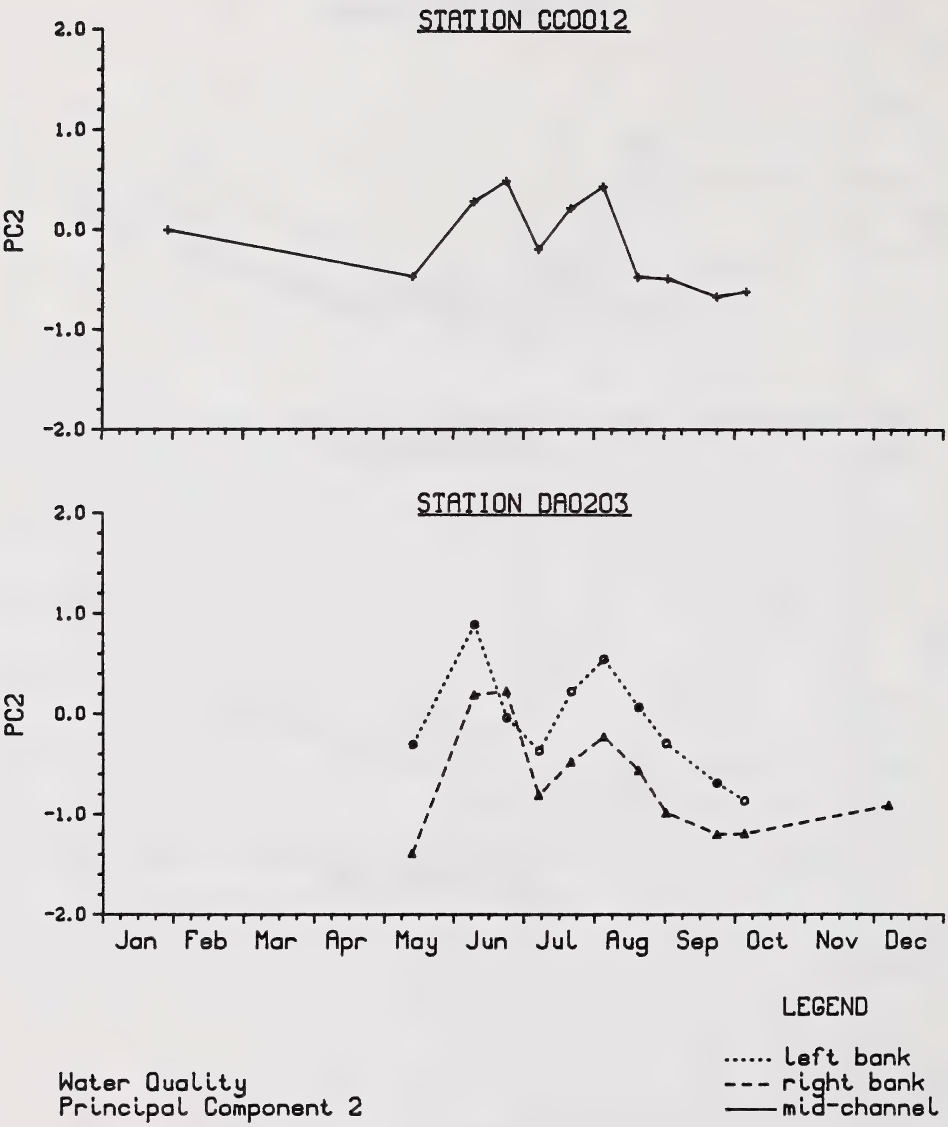

Figure 11. Principal component scores for water quality PC2 at five stations on the Athabasca River during 1981.

continued . . .

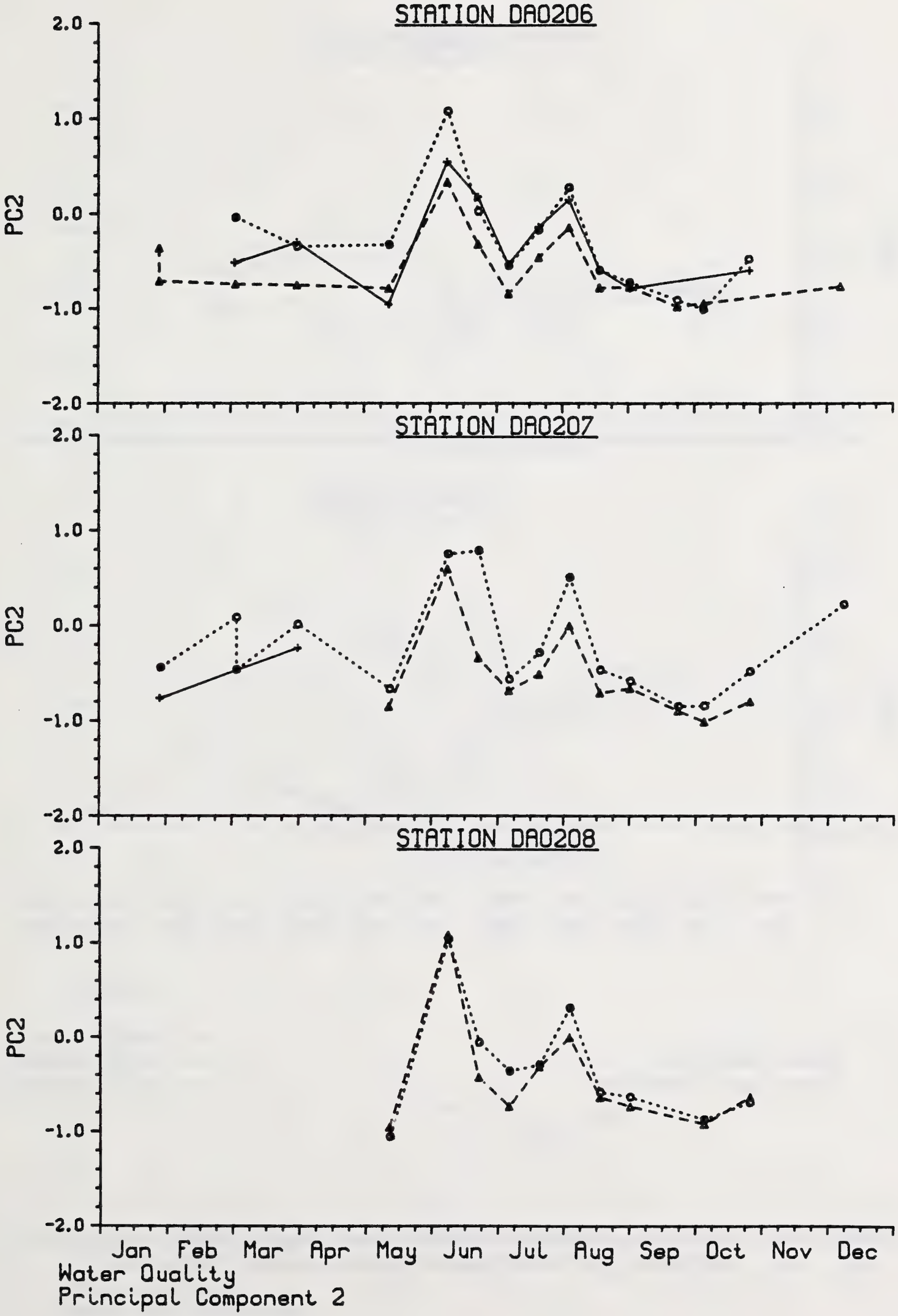

Figure 11. Concluded.

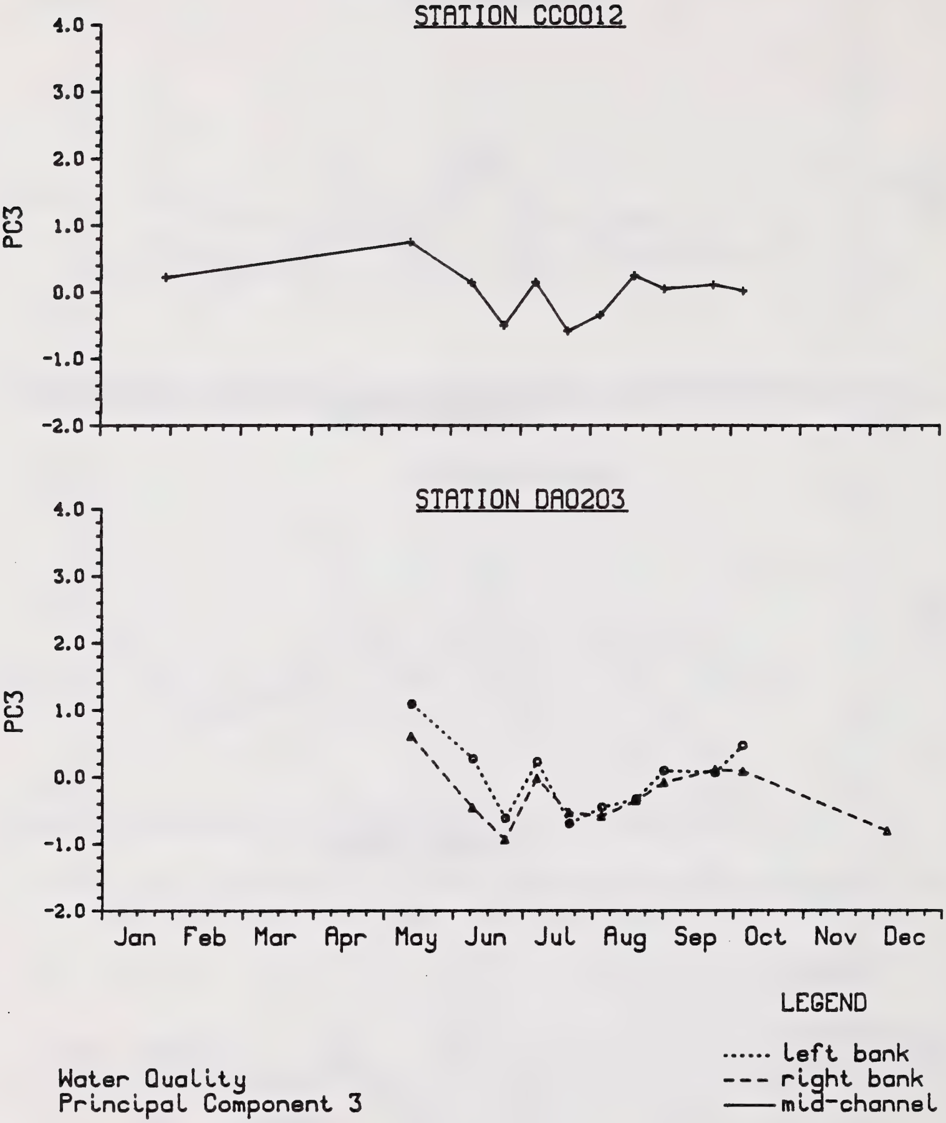

Figure 12. Principal component scores for water quality PC3 at five stations on the Athabasca River during 1981.

continued . . .

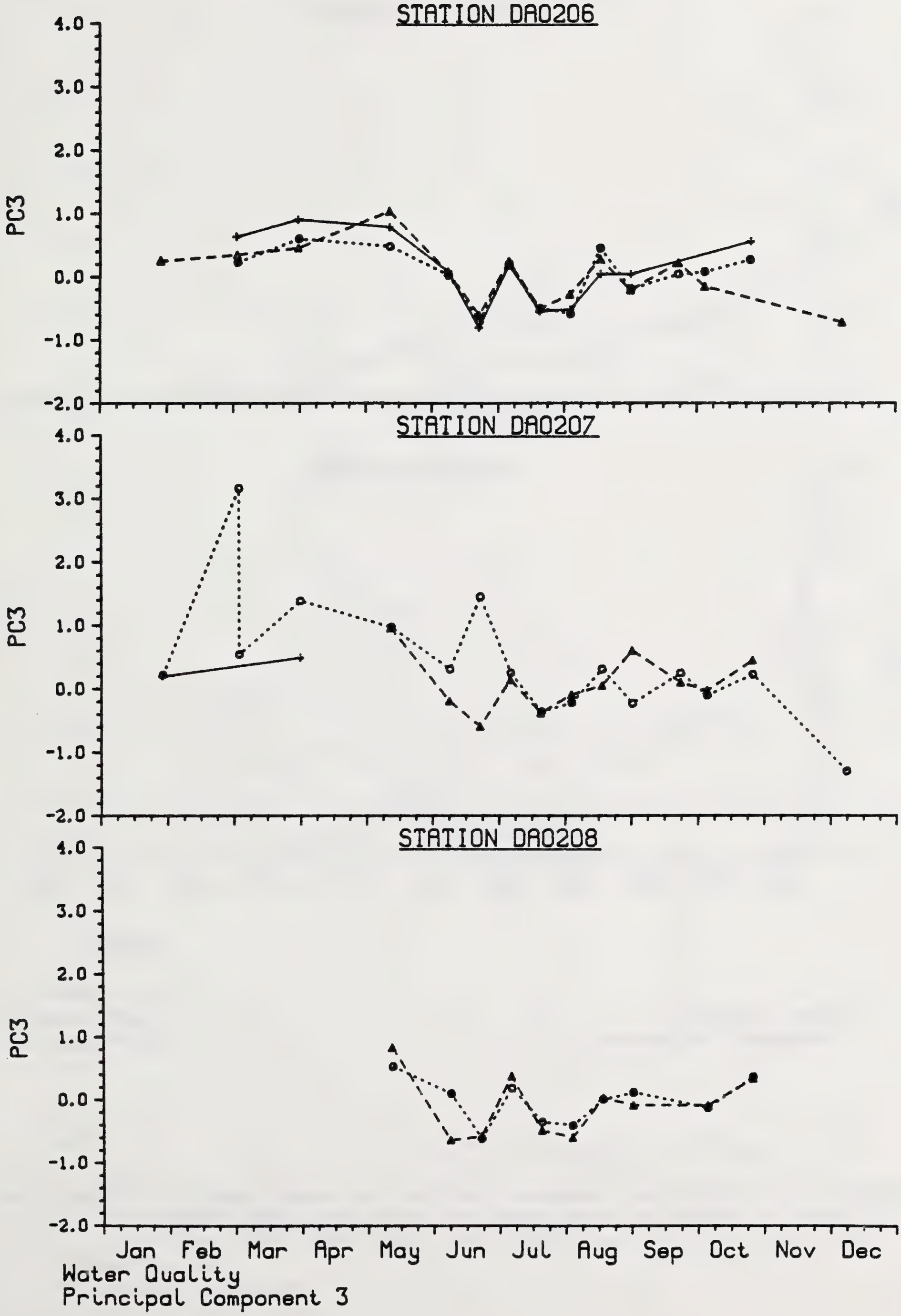

Figure 12. Concluded.

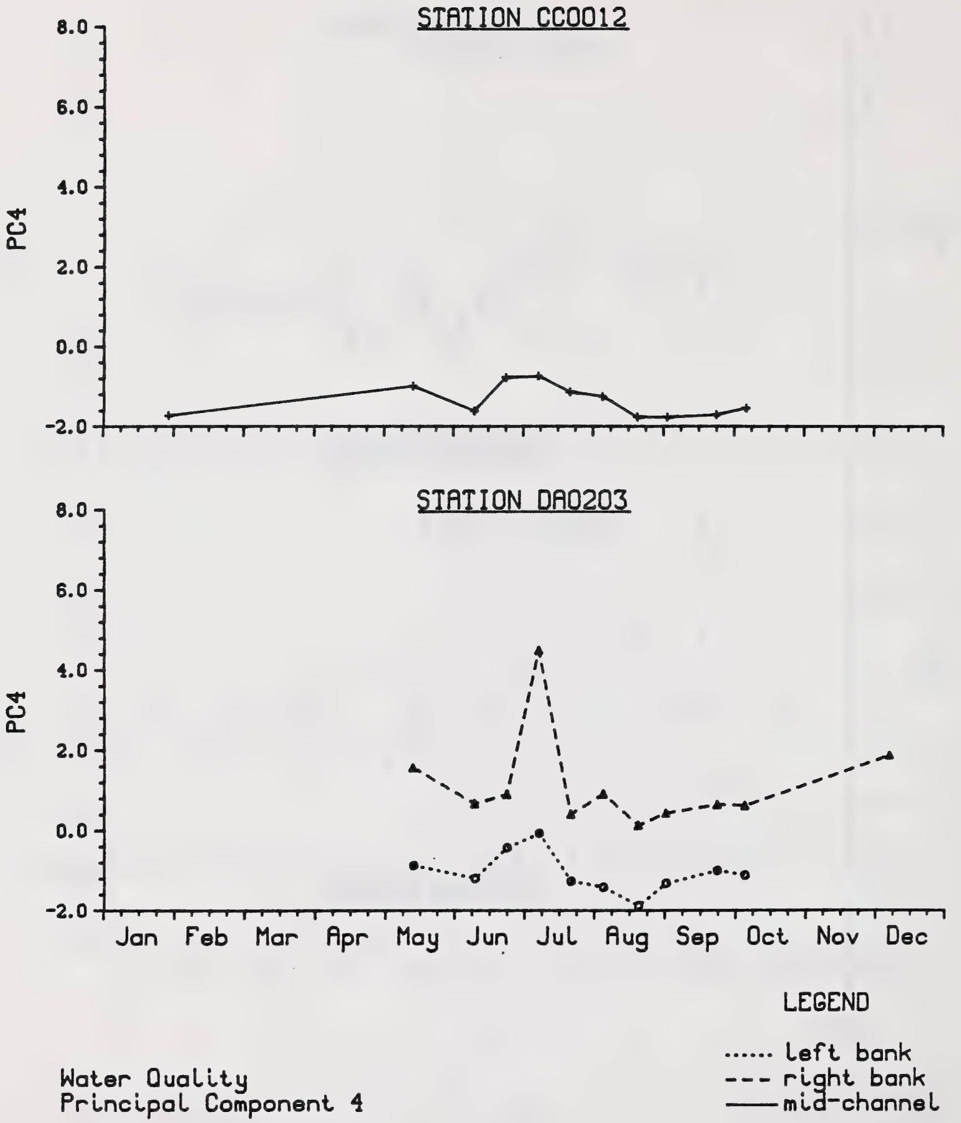

Figure 13. Principal component scores for water quality PC4 at five stations on the Athabasca River during 1981.

continued . . .

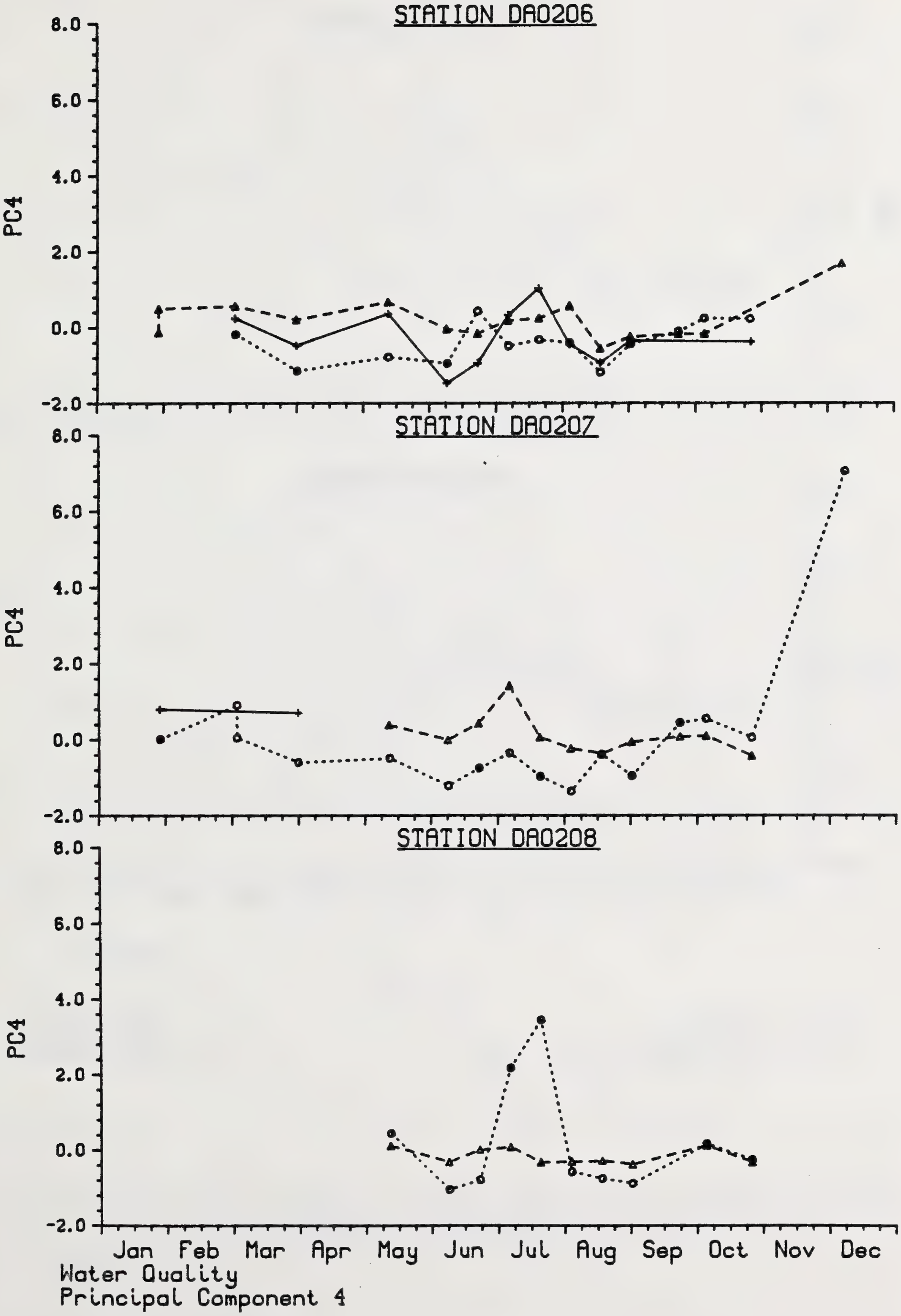

Figure 13. Concluded.

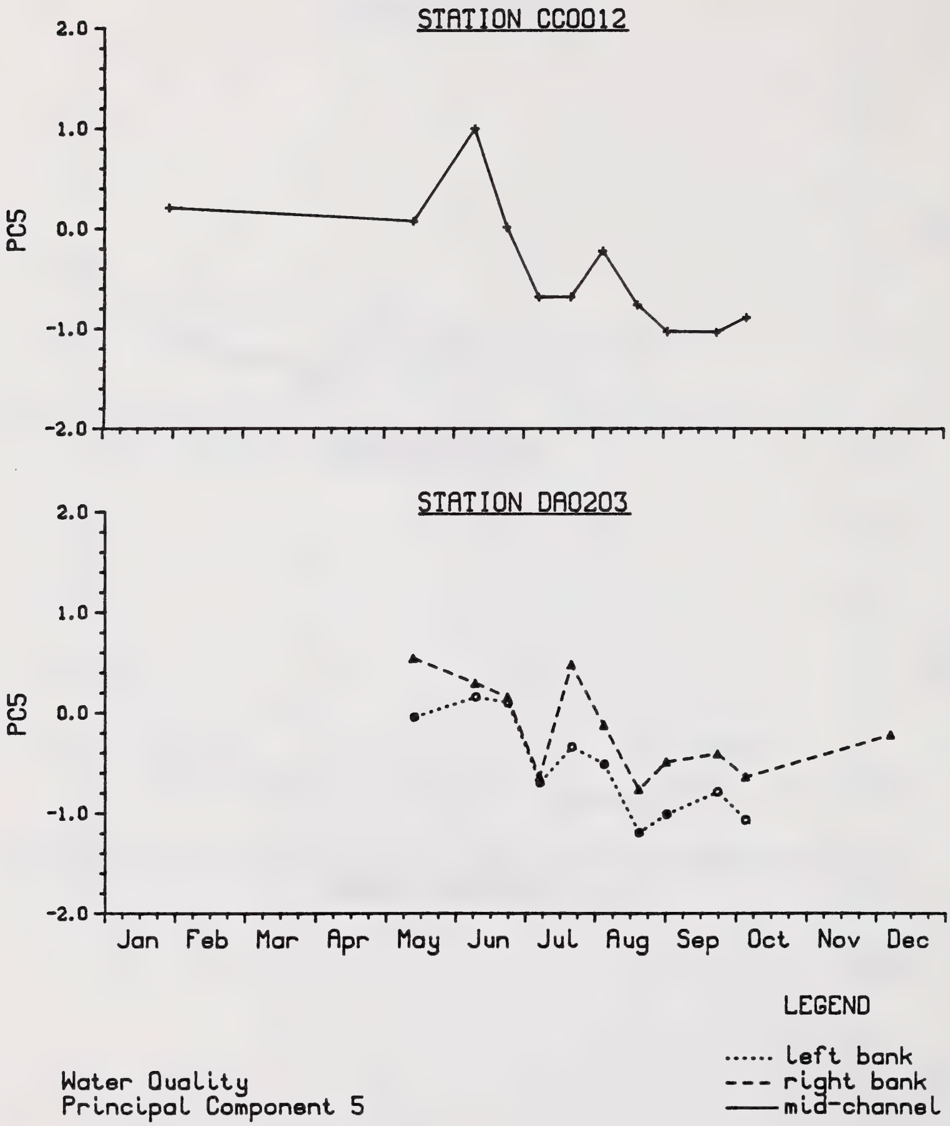

Figure 14. Principal component scores for water quality PC5 at five stations on the Athabasca River during 1981.

continued . . .

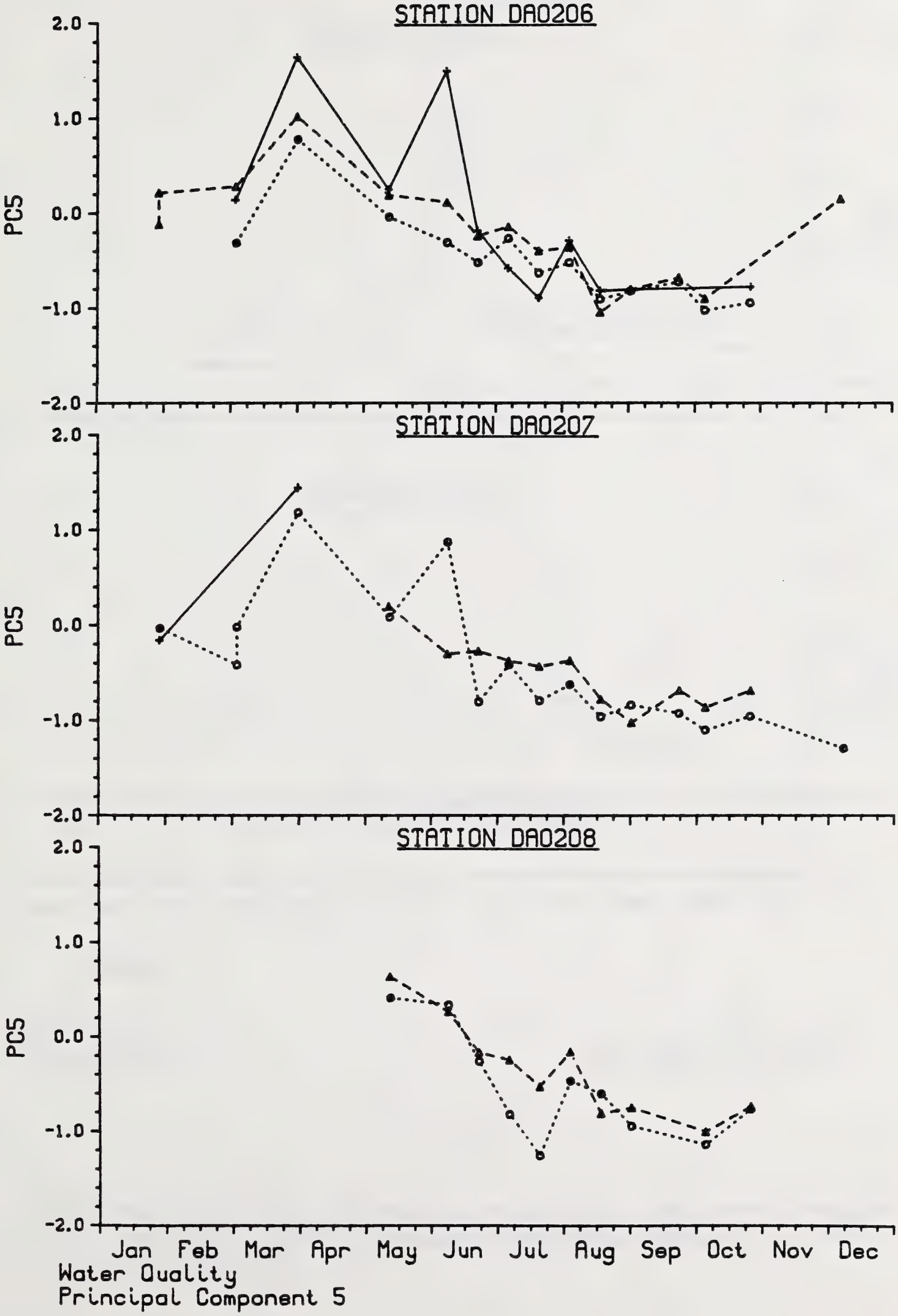

Figure 14. Concluded.

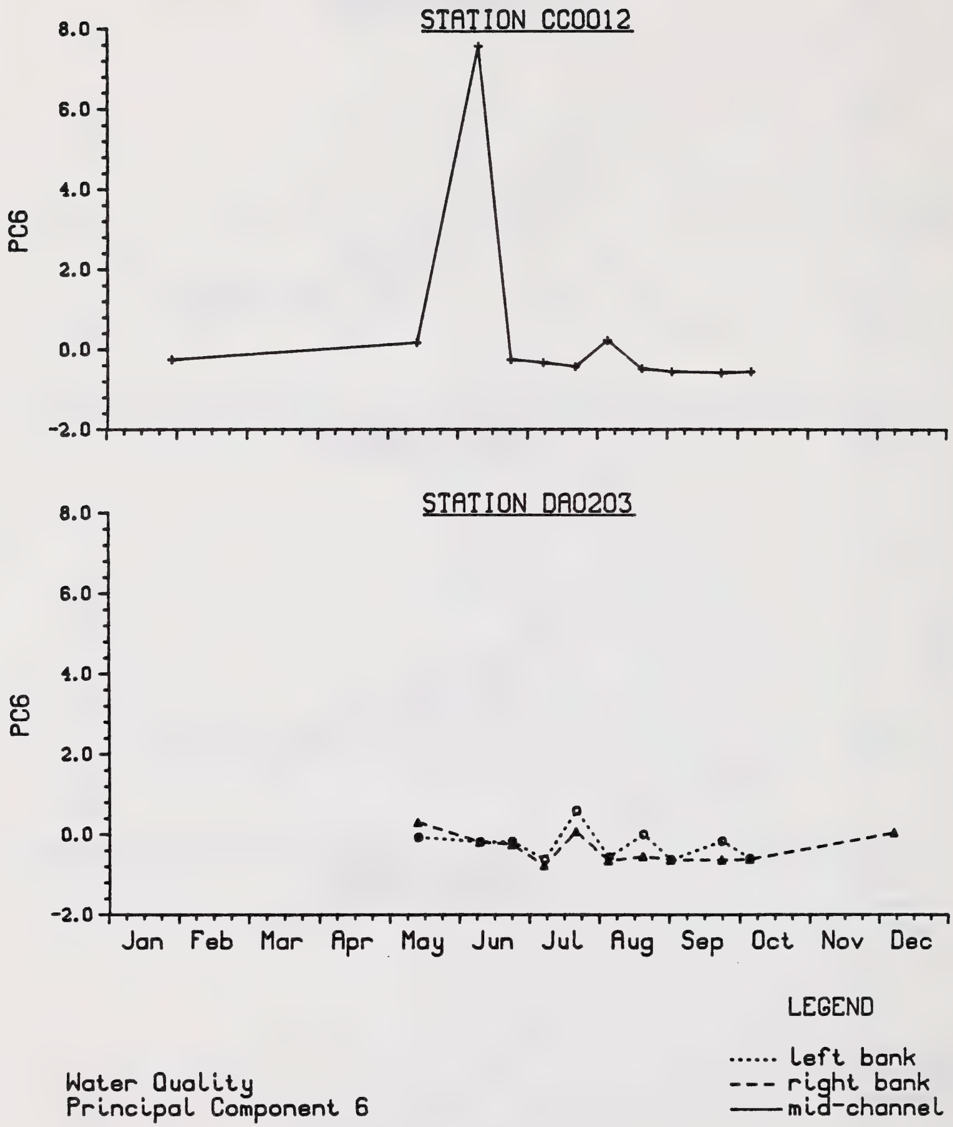

Figure 15. Principal component scores for water quality PC6 at five stations on the Athabasca River during 1981.

continued . . .

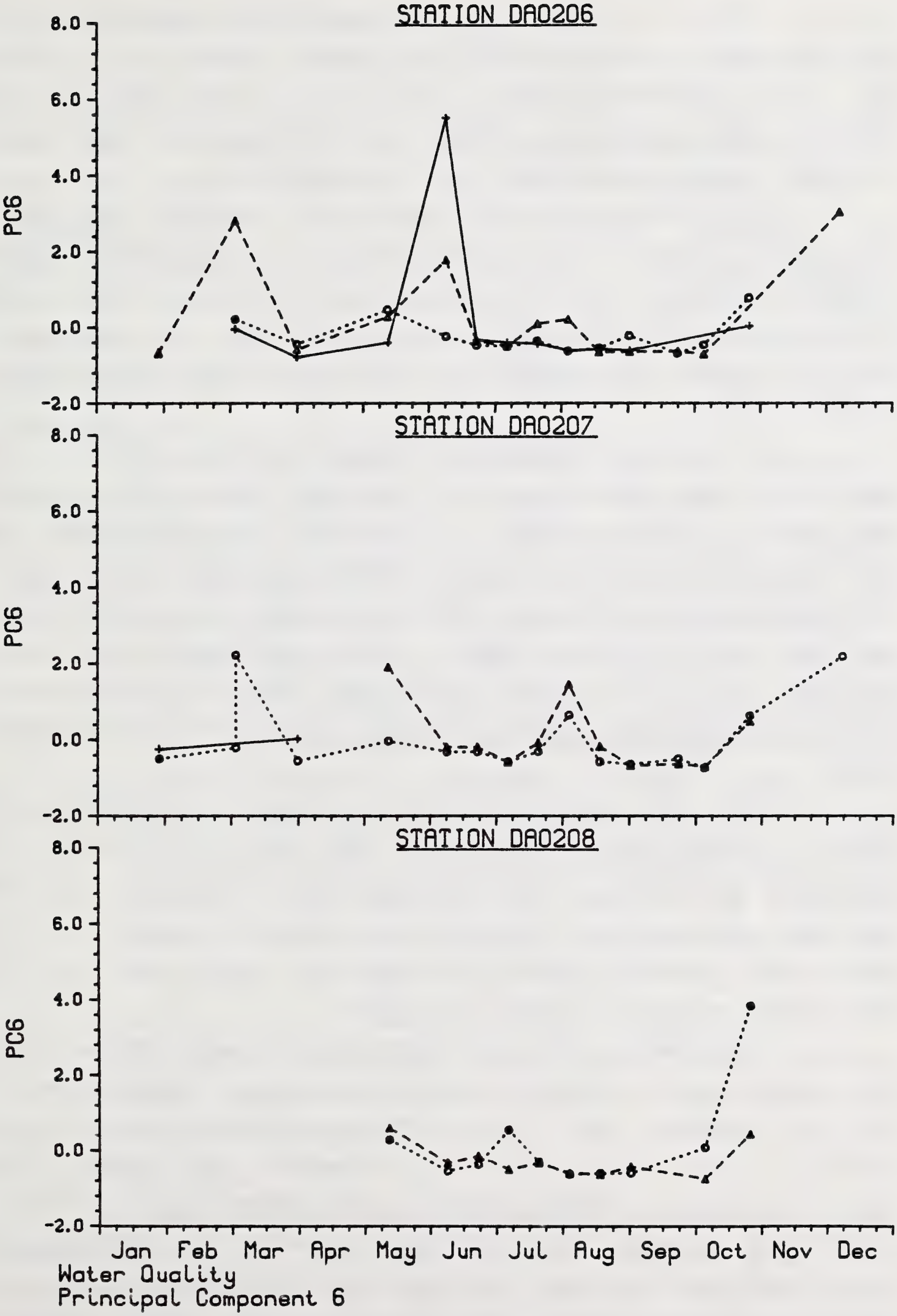

Figure 15. Concluded.

October. Differences between left and right banks were smaller and less consistent at stations DA0207 and DA0208. As was the case with PC1, these differences between the left and right sides of the Athabasca River appear to reflect the influences of right bank tributary streams, particularly the Clearwater River.

PC3, which is primarily a measure of potassium, lead, zinc, and copper, generally did not show substantial differences between stations, although an unusually high value did occur near the first of March in a left bank sample at Station DA0207. With few exceptions, PC3 scores were similar for both left and right bank samples at all stations.

The fourth PC (primarily a measure of sodium, chloride, and ammonia) had much higher values for right bank samples than for left bank samples at Station DA0203. PC4 was also frequently higher for right bank samples at both stations DA0206 and DA0207, but the differences between the left and right banks were not as large or as consistent as at Station DA0203. These differences are almost certainly due to the higher sodium and chloride concentrations present in right bank tributary streams, particularly the Clearwater River.

PC5, which represents primarily dissolved orthophosphate, showed a general declining trend from high values in the spring to low values in the fall, with some fluctuations in between. For the most part, there were no large differences between stations, but PC5 scores were frequently higher for right bank samples than for left bank samples at stations DA0203 and DA0206.

There were no consistent differences between left and right bank samples for PC6, which is primarily a measure of phenolic material. In addition, only a few differences between stations were apparent. Late in the year (after September), PC6 tended to be higher at stations DA0206, DA0207, and DA0208 than at Station DA0203. Two unusually large values were noted: one for a mid-channel sample taken near the first of June at Station CC0012, and one for another mid-channel sample taken near the same time at Station DA0206.

3.2 BENTHIC INVERTEBRATES

A separate principal component analysis was performed using benthic invertebrate abundance data from each of the months of May, June, July, and August of 1981. The principal components so derived were then used, instead of the individual benthic taxa, for subsequent analysis of variance and multiple comparisons tests comparing sampling stations. Interpretation of principal components was based simply on the abundance of the taxa most strongly associated with them. For reference purposes, the abundance data for each benthic invertebrate taxon are summarized in tables 20 to 23 (Appendix 7.2).

Although the benthic invertebrate data were subjected to detailed statistical analysis, the reader should be aware that, because of the way in which benthic sampling was conducted, application of statistical procedures is not entirely valid. Boerger (1983) gives the following description of the sampling procedure used:

> At each station, three replicate samples were collected, with the distance between samples being approximately 10 m. After the samples were placed in the collecting jar, they were examined for uniformity of sample volume. If the volume of detritus in the jars differed by more than 50%, more samples were collected and the three most similar ones chosen. This procedure was based on the correlation between detritus and density of organisms which has been frequently reported in the literature (cf. Rabeni and Minshall 1977). Such a selection procedure should reduce the variability between samples without biasing the sample mean, since there was no selection for either high or low volumes of detritus, but only for a uniform amount of detritus.

Given that the density of benthic invertebrates is correlated with detritus, this sample selection procedure would indeed reduce the variability among samples, the result being that sample variance always would be underestimated. The magnitude of the bias is unknown, but it is clear that it might be large. Since it appears that samples were collected only until three that were considered similar enough were obtained, the sample mean cannot be expected to be the same as the mean that would be obtained with random sampling (i.e., the sample mean is not an unbiased estimate).

The effect of underestimated variances, in terms of statistical hypothesis testing, would be a tendency toward accepting differences as being statistically significant when, in fact, they are not. Statistically significant differences that are merely artifacts of the sample selection procedure would tend to occur. The effect of bias of the sample mean is less predictable. In some instances it might tend to create false significant differences, and in others it might tend to obscure real differences.

In view of the above factors, which seriously affect the validity of statistical tests, detailed examination of all significant differences observed among stations with respect to benthic invertebrate populations was considered to be unwarranted. The results of statistical analyses and the conclusions drawn from them might well be erroneous.

In the following sections, the results of analysis of benthic invertebrate data are presented, with little discussion, for each of the months of May, June, July, and August. This is followed by a summary discussion that is restricted to consideration of only those stations that might be expected to show differences related to effluent sources or to the influence of the Clearwater River.

3.2.1 May 1981 Samples

The results of principal component analysis of benthic invertebrate data collected in May are presented in Table 3, which contains the PC loadings matrix. The first eight principal components accounted for 61% of the total variance. PC1 accounted for 14.3% of the total variance, and the amount of variance explained by each of PC3, PC4, PC5, PC6, PC7, and PC8 was 8.3%, 7.0%, 5.9%, 7.2%, 6.6%, 6.2%, and 5.6%, respectively. Details of which benthic invertebrate taxa are most closely associated (i.e., have loadings of at least 0.25 absolute value) with each PC are outlined in Table 4.

Table 3. Principal component loadings for the first eight principal components of benthic invertebrate abundance, May samples. Loadings greater than 0.25 absolute value are printed in boldface.

	Principal Component Loadings							
Taxon	PC 1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Nematomorpha	0.227	**0.321**	0.170	0.040	-0.229	**0.280**	0.108	**0.577**
Oligochaeta	**-0.291**	**0.833**	**-0.395**	-0.058	-0.100	-0.138	-0.152	-0.066
Siphlonurus	**-0.487**	-0.045	-0.095	0.229	0.153	**0.301**	**-0.426**	0.118
Baetis sp. A	**0.258**	-0.009	0.074	0.036	0.063	-0.239	0.069	**-0.401**
Heptagenia	**0.663**	0.144	**-0.330**	**0.458**	0.236	-0.243	0.095	**0.264**
Rhithrogena	**0.438**	-0.074	0.053	0.095	0.035	0.089	-0.220	-0.015
Metretopus	**-0.624**	0.087	0.145	**0.658**	-0.145	0.202	0.240	-0.079
Ephemerella	**0.324**	0.229	-0.182	-0.073	**-0.318**	0.038	**0.602**	-0.170
Baetisca	**0.279**	-0.011	-0.061	0.093	0.067	-0.242	-0.124	-0.085
Ophiogomphus	0.231	-0.115	0.048	0.170	-0.131	0.127	**-0.464**	0.063
Perlodidae	**0.633**	-0.108	**-0.389**	0.188	-0.193	**0.456**	-0.162	**-0.290**
Corixidae	-0.063	-0.020	0.169	0.040	**0.379**	-0.095	0.032	-0.128
Hydropsychidae	0.145	-0.105	**-0.255**	-0.213	0.219	0.061	0.232	**-0.315**
Ceratopogonidae	-0.133	0.182	-0.072	-0.109	**-0.277**	0.089	0.003	-0.124
Chironomidae	**0.379**	**0.556**	**0.633**	0.095	**0.286**	0.077	0.059	-0.182
Simuliidae	**-0.265**	0.064	**-0.369**	-0.164	**0.692**	**0.434**	0.196	0.037
Empididae	**0.271**	**0.373**	0.197	**-0.355**	**-0.259**	**0.515**	0.097	**0.267**

Principal component scores for each benthic sample are determined primarily by the abundances of the taxa indicated in Table 4 as being associated with each PC.

Analysis of variance, which was performed for each PC (Table 5), indicated that there were significant differences among sampling stations only with respect to PC2, PC3, PC6, and PC7. Multiple comparisons tests (which make all pairwise comparisons between stations) for each of these PCs are summarized in Table 6. The tests are for differences between mean PC scores, but the mean abundances for the benthic taxa most closely associated with each PC have been included to facilitate relating differences in PC scores to the specific taxa involved in each case. There were no significant differences in PC7 scores among station pairs despite the fact that analysis of variance detected significant ($P < 0.05$) variation in PC7 scores. This apparent contradiction is a result of the lower sensitivity of the multiple comparisons procedure.

3.2.2 June 1981 Samples

The principal component loadings matrix for benthic invertebrate samples collected during the month of June is presented in Table 7. In this sampling period, seven principal components accounted for 58% of the total variance in benthic invertebrate abundances. PC1 accounted for 16.4% and PC2 accounted for 11.6% of the total variance, while the amount of variance explained by each of PCs 3, 4, 5, 6, and 7 was 7.0%, 7.4%, 6.2%, 5.3%, and 4.3%, respectively. The interpretations of principal components, in terms of the benthic taxa most closely associated with each PC, are described in Table 8.

Analysis of variance results comparing sampling stations with respect to PC scores are summarized in Table 9. Significant differences among stations occurred only for PC2, PC3, and PC4. The specific differences between stations, with respect to these three PCs, were determined using the Student-Newman-Keuls multiple comparisons procedure, and the results of these comparisons are summarized in Table 10.

Table 4. Benthic invertebrate taxa with the highest absolute PC loadings (at least 0.25), May samples. Principal component scores are determined primarily by the log (no./m^2 + 1) of these taxa.

PC1:	*Heptagenia*	0.663		*Metretopus*	-0.624
	Perlodidae	0.633	vs.	*Siphlonurus*	-0.487
	Rhithrogena	0.438		Oligochaeta	-0.291
	Chironomidae	0.379		Simuliidae	-0.265
	Ephemerella	0.324			
	Baetisca	0.279			
	Empididae	0.271			
	Baetis sp. A	0.258			
PC2:	Oligochaeta	0.833			
	Chironomidae	0.556			
	Empididae	0.373			
	Nematomorpha	0.321			
PC3:	Chironomidae	0.633	vs.	Oligochaeta	-0.395
				Perlodidae	-0.389
				Simuliidae	-0.369
				Heptagenia	-0.330
				Hydropsychidae	-0.255
PC4:	*Metretopus*	0.658	vs.	Empididae	-0.355
	Heptagenia	0.458			
PC5:	Simuliidae	0.692	vs.	*Ephemerella*	-0.318
	Corixidae	0.379		Ceratopogonidae	-0.277
	Chironomidae	0.286		Empididae	-0.259

continued ....

Table 4. Concluded.

PC6:	Empididae	0.515			
	Perlodidae	0.456			
	Simuliidae	0.434			
	Siphlonurus	0.301			
	Nematomorpha	0.280			
PC7:	*Ephemerella*	0.602	vs.	*Ophiogomphus*	-0.464
				Siphlonurus	-0.426
PC8:	Nematomorpha	0.577	vs.	*Baetis* sp. A	-0.401
	Empididae	0.267		Hydropsychidae	-0.315
	Heptagenia	0.264		Perlodidae	-0.290

Table 5. Analysis of variance of benthic invertebrate principal component scores at the 16 sampling stations, May samples.

	Between Stations			Error			
Principal Component	Degrees of Freedom	Sum of Squares	Mean Squares	Degrees of Freedom	Sum of Squares	Mean Squares	F
PC1	15	12.686	0.846	80	82.314	1.029	0.82
PC2	15	34.152	2.277	80	60.848	0.761	2.99***
PC3	15	32.118	2.141	80	62.882	0.786	2.72**
PC4	15	21.763	1.451	80	73.237	0.916	1.59
PC5	15	23.625	1.575	80	71.376	0.892	1.77
PC6	15	36.688	2.446	80	58.312	0.729	3.36***
PC7	15	24.612	1.641	80	70.387	0.880	1.87*
PC8	15	10.925	0.728	80	84.075	1.051	0.69

* significant with $P < 0.05$

** significant with $P < 0.01$

*** significant with $P < 0.001$

Table 6. Results of Student-Newman-Keuls multiple comparisons tests of benthic invertebrate principal component scores at each sampling station, May samples. Significant differences are indicated by the lines below the mean PC scores. Stations joined by the same line were not significantly different ($P > 0.05$) from each other. Only stations that were significantly different from at least one other station are included. Abundance of taxa with the highest loadings (at least 0.25 absolute value) on each PC are included in the upper part of each table section.

PC2:

	PC	Mean No./m^2 at Each Station				
Taxon	Loading	8E	3W	4W	4E	5E
Oligochaeta	0.833	1.7	6.7	1.7	86.7	45.0
Chironomidae	0.556	55.0	81.7	118.3	113.3	953.3
Empididae	0.373	3.3	13.0	0.0	0.0	6.7
Nematomorpha	0.321	0.0	0.0	0.0	0.0	5.0
Mean PC2 Score:		-1.229	-0.971	-0.764	0.621	1.129

continued . . .

Table 6. Concluded.

PC3:

Taxon	PC Loading	Mean No./m^2 at Each Station					
		5W	8W	7W	4E	6E	5E
Chironomidae	0.633	103.3	125.0	170.0	113.3	280.0	953.3
Oligochaeta	-0.395	28.3	21.7	55.0	86.7	20.0	45.0
Perlodidae	-0.389	73.3	68.3	58.3	26.7	10.0	8.3
Simuliidae	-0.369	11.7	220.0	21.7	0.0	0.0	11.7
Heptagenia	-0.330	16.7	10.0	16.7	20.0	3.3	0.0
Hydropsychidae	-0.255	6.7	10.0	0.0	0.0	0.0	0.0
Mean PC3 Score:		-0.712	-0.675	-0.670	-0.399	1.238	1.354

PC6:

Taxon	PC Loading	Mean No./m^2 at Each Station						
		4E	7E	1E	3W	8W	5W	6W
Empididae	0.515	0.0	3.3	0.0	13.3	11.7	6.7	10.0
Perlodidae	0.456	26.7	23.3	85.0	170.0	68.3	73.3	135.0
Simuliidae	0.434	0.0	8.3	0.0	0.0	220.0	11.7	13.3
Siphlonurus	0.301	0.0	8.3	1.7	10.0	1.7	11.7	0.0
Nematomorpha	0.280	0.0	0.0	3.3	0.0	8.3	1.7	10.0
Mean PC6 Score:		-1.094	-0.885	-0.813	0.613	0.712	0.783	0.945

Table 7. Principal component loadings for the first seven principal components of benthic invertebrate abundance, June samples. Loadings greater than 0.25 absolute value are printed in boldface.

Taxon	Principal Component Loadings						
	PC 1	PC2	PC3	PC4	PC5	PC6	PC7
Nematomorpha	0.070	0.008	**0.342**	0.055	0.042	0.223	0.027
Oligochaeta	**0.438**	**-0.476**	**0.584**	0.216	-0.148	0.205	-0.011
Hydracarina	0.047	**0.276**	-0.049	0.147	0.218	0.045	0.135
Ameletus	0.189	0.144	**-0.378**	**-0.406**	-0.032	-0.010	-0.202
Isonychia	**0.671**	0.239	**0.253**	-0.059	-0.093	-0.142	**-0.292**
Baetis sp. A	-0.184	**0.696**	**0.422**	0.215	**-0.281**	0.141	0.100
Baetis sp. C	0.025	0.163	0.018	-0.052	0.244	-0.234	**0.272**
Centroptilum sp. 1	0.017	0.101	-0.073	0.167	**0.305**	0.027	-0.008
Cloeon sp. 1	**0.503**	0.104	**-0.377**	**0.299**	0.139	-0.029	0.021
Pseudocloeon	**0.278**	**0.393**	-0.188	**0.316**	**0.373**	0.211	**0.307**
Heptagenia	**0.614**	**0.559**	0.076	**-0.346**	-0.009	-0.043	0.084
Ametropus	-0.110	**-0.250**	0.207	0.233	**0.677**	0.179	-0.110
Metretopus	-0.052	**0.399**	-0.045	0.192	0.073	**0.620**	**-0.399**
Ephemerella	**-0.290**	**0.484**	0.022	-0.107	**0.351**	0.008	**0.310**
Tricorythodes	**0.738**	-0.022	0.059	**-0.298**	**0.309**	0.053	-0.234

continued ....

Table 7. Concluded.

Taxon	Principal Component Loadings						
	PC 1	PC2	PC3	PC4	PC5	PC6	PC7
Brachycercus	**0.366**	0.230	-0.197	**0.362**	**-0.348**	0.063	-0.201
Caenis	**0.719**	0.072	**-0.373**	**0.375**	-0.152	-0.094	-0.074
Ophiogomphus	**0.421**	**0.271**	0.098	**0.337**	0.041	-0.244	**0.267**
Perlodidae	**-0.291**	**0.749**	0.202	-0.002	0.149	-0.208	-0.198
Hydropsychidae	0.370	0.088	0.050	**-0.500**	0.062	0.047	0.011
Ceratopogonidae	0.013	-0.080	**0.303**	**0.481**	**0.299**	**-0.543**	-0.185
Chironomidae	**0.747**	-0.227	0.161	-0.018	0.035	0.197	**0.359**
Simuliidae	**0.327**	**-0.268**	**0.416**	-0.144	-0.082	**-0.334**	-0.082

Table 8. Benthic invertebrate taxa with the highest absolute PC loadings (at least 0.25), June samples. Principal component scores are determined primarily by the log (no./m^2 + 1) of these taxa.

PC1:	Chironomidae	0.747	vs.	Perlodidae	-0.291
	Tricorythodes	0.738		*Ephemerella*	-0.290
	Caenis	0.719			
	Isonychia	6.671			
	Heptagenia	0.614			
	Cloeon sp. 1	0.503			
	Oligochaeta	0.438			
	Ophiogomphus	0.421			
	Hydropsychidae	0.370			
	Brachycercus	0.366			
	Simuliidae	0.327			
	Pseudocloeon	0.278			
PC2:	Perlodidae	0.749	vs.	Oligochaeta	-0.476
	Baetis sp. A	0.696		Simuliidae	-0.266
	Heptagenia	0.559		*Ametropus*	-0.250
	Ephemerella	0.484			
	Metretopus	0.399			
	Pseudocloeon	0.393			
	Hydracarina	0.276			
	Ophiogomphus	0.271			

continued . . .

Table 8. Concluded.

PC3:	Oligochaeta	0.584	vs.	*Ameletus*	-0.378
	Baetis sp. A	0.422		*Cloeon* sp. 1	-0.377
	Simuliidae	0.416		*Caenis*	-0.373
	Nematomorpha	0.342			
	Ceratopogonidae	0.303			
	Isonychia	0.253			
PC4:	Ceratopogonidae	0.481	vs.	Hydropsychidae	-0.500
	Caenis	0.375		*Ameletus*	-0.406
	Brachycercus	0.362		*Heptagenia*	-0.346
	Ophiogomphus	0.337		*Tricorythodes*	-0.298
	Pseudocloeon	0.316			
	Cloeon sp. 1	0.299			
PC5:	*Ametropus*	0.677	vs.	*Brachycercus*	-0.348
	Pseudocloeon	0.373		*Baetis* sp. A	-0.281
	Ephemerella	0.351			
	Tricorythodes	0.309			
	Centroptilum sp. 1	0.305			
	Ceratopogonidae	0.299			
PC6:	*Metretopus*	0.620	vs.	Ceratopogonidae	-0.543
				Simuliidae	-0.334
PC7:	Chironomidae	0.359	vs.	*Metretopus*	-0.399
	Ephemerella	0.310		*Isonychia*	-0.292
	Pseudocloeon	0.307			
	Baetis sp. C	0.272			
	Ophiogomphus	0.267			

Table 9. Analysis of variance of benthic invertebrate principal component scores at the 16 sampling stations, June samples.

	Between Stations			Error			
Principal Component	Degrees of Freedom	Sum of Squares	Mean Squares	Degrees of Freedom	Sum of Squares	Mean Squares	F
PC1	15	22.472	1.498	80	72.529	0.907	1.65
PC2	15	55.091	3.673	80	39.909	0.499	7.36***
PC3	15	35.367	2.358	80	59.634	0.745	3.16***
PC4	15	48.486	3.232	80	46.514	0.581	5.56***
PC5	15	23.612	1.574	80	71.389	0.892	1.76
PC6	15	21.217	1.414	80	73.783	0.922	1.53
PC7	15	14.673	0.978	80	80.327	1.004	0.97

*** significant with $P < 0.001$

Table 10. Results of Student - Newman - Keuls multiple comparisons tests of benthic invertebrate principal component scores at each sampling station, June samples. Significant differences are indicated by the lines below the mean PC scores. Stations joined by the same line are not significantly different (P > 0.5) from each other. Only stations that were significantly different from at least one other station are included. Abundances of taxa with the highest loadings (at least 0.25 absolute value) on each PC are included in the upper part of each table section.

PC2:

	PC	Mean No./m^2 at Each Station														
Taxon	Loading	1E	8E	8W	2E	1W	2W	7W	5E	5W	4W	3E	7E	4E	3W	6E
Perlodidae	0.749	1.7	0.0	28.0	5.0	40.0	40.0	18.3	13.3	30.0	30.0	36.7	20.0	95.0	51.7	30.0
Baetis sp. A	0.696	0.0	1.7	1.7	15.0	23.3	16.7	20.0	40.0	8.3	16.7	106.7	23.3	101.7	78.3	25.0
Heptagenia	0.559	10.0	6.7	18.3	30.0	8.3	30.0	140.0	175.0	355.0	250.0	118.3	150.0	290.0	281.7	248.3
Ephemerella	0.484	0.0	6.6	0.0	0.0	1.7	10.0	0.0	16.7	15.0	16.7	1.7	1.7	11.7	6.7	8.3
Metretopus	0.399	6.6	0.0	0.0	5.0	3.3	8.3	5.0	28.3	1.7	21.7	11.7	35.0	3.3	10.0	38.3
Pseudocloeon	0.393	0.0	0.0	3.3	1.7	0.0	1.7	0.0	35.0	10.0	15.0	3.3	21.7	26.7	0.0	20.0
Hydracarina	0.276	0.0	0.0	0.0	5.0	0.0	0.0	0.0	3.3	0.0	1.7	0.0	8.3	1.7	11.7	1.7
Ophiogomphus	0.271	3.3	0.0	0.0	13.3	21.7	0.0	5.0	11.7	6.7	6.7	5.0	11.7	6.7	23.3	21.7
Oligochaeta	-0.476	613.3	198.3	211.7	310.0	638.3	366.7	141.7	563.3	140.0	171.7	78.3	41.7	45.0	231.7	98.3
Simuliidae	-0.266	1.7	10.0	10.0	5.0	10.0	1.7	0.0	1.7	16.7	0.0	6.7	0.0	28.3	3.3	3.3
Ametropus	-0.250	0.0	0.0	26.7	13.3	30.0	80.0	0.0	21.7	0.0	0.0	23.3	0.0	0.0	6.7	3.3
Mean PC2 Score:		-1.328	-1.287	-1.062	-0.553	-0.454	-0.439	0.067	0.253	0.333	0.542	0.639	0.716	0.864	0.891	0.984

PC3:

	PC	Mean No./m^2 at Each Station					
Taxon	Loading	7E	6W	3E	2W	4E	3W
Oligochaeta	0.584	41.7	110.0	78.3	366.7	45.0	231.7
Baetis sp. A	0.422	23.3	0.0	106.7	16.7	101.7	78.3
Simuliidae	0.416	0.0	0.0	6.7	1.7	28.3	3.3
Nematomorpha	0.342	5.0	0.0	1.7	13.3	3.3	0.0
Ceratopogonidae	0.303	10.0	0.0	26.7	20.0	6.7	8.3
Isonychia	0.253	1.7	1.7	3.3	0.0	18.3	25.0
Ameletus	-0.378	3.3	15.0	0.0	0.0	16.7	0.0
Cloeon sp. 1	-0.377	58.3	6.7	15.0	0.0	0.0	0.0
Caenis	-0.373	105.0	13.3	3.3	0.0	1.7	13.3
Mean PC3 Score:		-1.179	-1.094	0.616	0.689	0.793	1.035

continued . . .

Table 10. Concluded.

PC4:

Taxon	PC Loading	Mean No./m^2 at Each Station 4E	6W	5W	4W	7W	2E	3E	7E	6E	5E
Ceratopogonidae	0.481	6.7	0.0	6.7	0.0	0.0	15.0	26.7	10.0	0.0	6.7
Caenis	0.375	1.7	13.3	0.0	31.7	13.3	98.3	3.3	105.0	211.7	170.0
Brachycercus	0.362	1.7	6.7	0.0	0.0	3.3	3.3	5.0	10.0	20.0	15.0
Ophiogomphus	0.337	6.7	1.7	6.7	6.7	5.0	13.3	5.0	11.7	21.7	11.7
Pseudocloeon	0.316	26.7	0.0	10.0	15.0	0.0	1.7	3.3	21.7	20.0	35.0
Cloeon sp. 1	0.299	0.0	6.7	1.7	1.7	1.7	30.0	15.0	58.3	18.3	30.0
Hydropsychidae	-0.500	11.7	1.7	11.7	10.0	10.0	0.0	0.0	0.0	25.0	0.0
Ameletus	-0.406	16.7	15.0	0.0	16.7	5.0	0.0	0.0	3.3	1.7	0.0
Heptagenia	-0.346	290.0	108.3	355.0	250.0	140.0	30.0	118.3	150.0	248.3	175.0
Tricorythodes	-0.298	28.3	11.6	8.3	121.7	0.0	41.7	6.7	13.3	133.3	221.7
Mean PC4 Score:		-0.978	-0.963	-0.939	-0.820	-0.712	0.588	0.630	0.845	0.896	1.186

3.2.3 July 1981 Samples

The principal component loadings for benthic taxa collected during the month of July are presented in Table 11. In July, the first eight principal components accounted for 65% of the total variance in the abundances of the taxa collected. The amount of variance explained by each of PC1, PC2, and PC3 was 15.5%, 13.3%, and 8.9%. PC4, PC5, PC6, PC7, and PC8 accounted for 6.0%, 6.7%, 5.4%, 5.3%, and 4.3%, respectively, of the total variance. The composition of the eight principal components, in terms of the major constituent taxa, are described for each PC in Table 12.

Analysis of variance of the principal component scores for each PC indicated that significant differences among stations involved all principal components except PC8. Multiple comparisons tests, which compare all pairs of stations, were performed for all PCs for which a significant difference was indicated by analysis of variance. The results of these pairwise comparisons are summarized in Table 14. In July, there were more significant differences between stations, involving more principal components, than in either May or June.

3.2.4 August 1981 Samples

Results of principal component analysis of the August benthic invertebrate samples are presented in Table 15, which includes the PC loadings for each of the benthic taxa. The first eight principal components accounted for 68% of the total variance of the benthic invertebrate abundances in August. PC1 accounted for 15.0% and PC2 accounted for 12.9% of the total variance. PCs 3, 4, 5, 6, 7, and 8 explained 8.9%, 7.2%, 7.3%, 5.8%, 5.7%, and 5.0%, respectively, of the total variance. Descriptions of the eight principal components, in terms of the benthic taxa most closely associated with each PC, are given in Table 16. Five of the principal components (PC1, PC2, PC3, PC4, and PC6) showed significant differences among stations when tested by analysis of variance (Table 17). The details of which stations were significantly different from which other stations (as determined by multiple comparisons tests) are summarized in Table 18.

Table 11. Principal component loadings for the first eight principal components of benthic invertebrate abundance, July samples. Loadings greater than 0.25 absolute value are printed in boldface.

	Principal Component Loadings							
Taxon	PC 1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Nematomorpha	**0.277**	0.217	**0.769**	0.127	-0.121	0.220	0.031	-0.143
Oligochaeta	-0.009	**-0.281**	**0.691**	0.078	**0.337**	0.153	0.179	**0.266**
Cladocera	**0.439**	**0.734**	0.109	0.077	-0.104	-0.245	-0.035	0.069
Ostracoda	-0.017	0.180	**0.279**	0.120	**0.506**	**-0.316**	0.212	-0.046
Collembola	**0.382**	0.191	-0.082	0.003	**0.388**	**0.478**	**-0.274**	-0.184
Ameletus	**0.301**	-0.152	0.143	**-0.326**	0.108	-0.101	**0.619**	0.011
Isonychia	**0.475**	**-0.535**	0.048	**-0.351**	**-0.369**	0.127	0.067	0.023
Baetis sp. A	0.160	-0.215	**0.402**	-0.109	**-0.409**	**0.261**	**-0.428**	0.095
Baetis sp. X	0.190	**-0.388**	**-0.264**	0.228	-0.034	-0.090	0.066	**0.707**
Centroptilum sp. 1	**0.334**	0.235	-0.048	0.022	0.117	0.154	-0.083	0.231
Cloeon sp. 1	**0.429**	**0.757**	-0.001	**-0.253**	-0.102	-0.030	0.102	0.112
Pseudocloeon	0.225	0.228	**-0.473**	-0.216	**0.312**	**0.411**	0.205	-0.050
Heptagenia	**0.677**	**-0.383**	**-0.301**	-0.189	0.141	0.030	0.017	-0.050
Ametropus	0.157	-0.134	-0.223	**0.598**	**-0.281**	-0.047	**0.449**	**-0.369**
Leptophlebia	0.200	0.145	-0.099	-0.129	**0.311**	0.044	-0.028	-0.007

continued ....

Table 11. Concluded.

Taxon	Principal Component Loadings							
	PC 1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Ephemerella	**0.327**	**-0.310**	0.118	**-0.315**	-0.073	**-0.322**	0.093	-0.024
Tricorythodes	**0.714**	**-0.436**	0.128	0.164	0.036	-0.091	-0.092	0.053
Caenis	**0.829**	-0.012	-0.141	0.213	0.136	-0.166	-0.234	-0.104
Ophiogomphus	**0.588**	-0.045	-0.082	0.188	-0.145	**0.401**	**0.304**	0.006
Hydropsychidae	0.183	**-0.533**	0.150	**-0.359**	0.067	**-0.332**	-0.063	**-0.299**
Ceratopogonidae	0.038	-0.126	-0.071	**0.317**	-0.136	0.151	-0.104	0.000
Chironomidae	0.242	**-0.490**	**0.269**	0.131	**0.478**	-0.035	-0.025	0.019

Table 12. Benthic invertebrate taxa with the highest absolute PC loadings (at least 0.25), July samples. Principal component scores are determined primarily by the log (no./m^2 + 1) of these taxa.

PC1:	*Caenis*	0.829			
	Tricorythodes	0.714			
	Heptagenia	0.677			
	Ophiogomphus	0.588			
	Isonychia	0.475			
	Cladocera	0.439			
	Cloeon sp. 1	0.429			
	Collembola	0.382			
	Centroptilum sp. 1	0.334			
	Ephemerella	0.327			
	Ameletus	0.301			
	Nematomorpha	0.277			
PC2:	*Cloeon* sp. 1	0.757	vs.	*Isonychia*	-0.535
	Cladocera	0.734		Hydropsychidae	-0.533
				Chironomidae	-0.490
				Tricorythodes	-0.436
				Baetis sp. X	-0.388
				Heptagenia	-0.383
				Ephemerella	-0.310
				Oligochaeta	-0.281
PC3:	Nematomorpha	0.769	vs.	*Pseudocloeon*	-0.473
	Oligochaeta	0.691		*Heptagenia*	-0.301
	Baetis sp. A	0.402		*Baetis* sp. X	-0.264
	Ostracoda	0.279			
	Chironomidae	0.269			

continued ....

Table 12. Concluded.

PC4:	*Ametropus*	0.598	vs.	Hydropsychidae	-0.359
	Ceratopogonidae	0.317		*Isonychia*	-0.351
				Ameletus	-0.326
				Ephemerella	-0.315
				Cloeon sp. 1	-0.253
PC5:	Ostracoda	0.506	vs.	*Baetis* sp. A	-0.409
	Chironomidae	0.478		*Isonychia*	-0.369
	Collembola	0.388		*Ametropus*	-0.281
	Oligochaeta	0.337			
	Pseudocloeon	0.312			
	Leptophlebia	0.311			
PC6:	Collembola	0.478	vs.	Hydropsychidae	-0.332
	Pseudocloeon	0.411		*Ephemerella*	-0.322
	Ophiogomphus	0.401		Ostracoda	-0.316
	Baetis sp. A	0.261			
PC7:	*Ameletus*	0.619	vs.	*Baetis* sp. A	-0.428
	Ametropus	0.449		Collembola	-0.274
	Ophiogomphus	0.304			
PC8:	*Baetis* sp. X	0.707	vs.	*Ametropus*	-0.369
	Oligochaeta	0.266		Hydropsychidae	-0.299

Table 13. Analysis of variance of benthic invertebrate principal component scores at the 16 sampling stations, July samples.

	Between Stations			Error			
Principal Component	Degrees of Freedom	Sum of Squares	Mean Squares	Degrees of Freedom	Sum of Squares	Mean Squares	F
PC1	15	53.456	3.564	80	41.544	0.519	6.86***
PC2	15	31.497	2.100	80	63.504	0.794	2.65**
PC3	15	33.068	2.205	80	61.933	0.774	2.85**
PC4	15	39.868	2.658	80	55.131	0.689	3.86***
PC5	15	38.159	2.544	80	56.841	0.711	3.58***
PC6	15	28.610	1.907	80	66.391	0.830	2.30**
PC7	15	27.995	1.866	80	67.005	0.838	2.23*
PC8	15	20.405	1.360	80	74.595	0.932	1.46

* significant with $P < 0.05$

** significant with $P < 0.01$

*** significant with $P < 0.001$

Table 14. Results of Student - Newman - Keuls multiple comparisons tests of benthic invertebrate principal component scores at each sampling station, July samples. Significant differences are indicated by the lines below the mean PC scores. Stations joined by the same line are not significantly different (P > 0.5) from each other. Only stations that were significantly different from at least one other station are included. Abundances of taxa with the highest loadings (at least 0.25 absolute value) on each PC are included in the upper part of each table section.

PC1:

Taxon	PC Loading	Mean No./m^2 at Each Station 8W	8E	5W	6W	4E	2W	1W	1E	4W	7W	5E	6E	2E	3W	3E	7E
Caenis	0.829	0.0	3.3	1.7	28.3	1.7	30.0	21.7	25.0	20.0	48.3	103.3	91.7	43.3	36.7	131.7	328.3
Tricorythodes	0.714	10.0	6.7	6.7	68.3	141.7	63.3	128.3	76.7	36.7	125.0	165.0	78.3	111.7	56.7	168.3	225.0
Heptagenia	0.677	56.7	13.3	113.3	616.7	120.0	153.3	156.7	295.0	170.0	401.7	213.3	51.7	196.7	328.3	310.0	323.3
Ophiogomphus	0.588	1.7	0.0	3.3	10.0	5.0	18.3	20.0	25.0	10.0	15.0	16.7	18.3	30.0	30.0	5.0	20.0
Isonychia	0.475	0.0	0.0	10.0	13.3	18.3	3.3	15.0	90.0	83.3	0.0	23.3	0.0	8.3	125.0	31.7	5.0
Cladocera	0.439	0.0	8.3	13.3	10.0	18.3	30.0	1.7	3.3	0.0	1.7	103.3	216.7	10.0	56.7	103.3	268.3
Cloeon sp. 1	0.429	0.0	5.0	26.7	6.7	121.7	121.7	6.7	90.0	65.0	11.6	173.3	286.6	121.7	96.7	205.0	591.7
Collembola	0.382	0.0	0.0	0.0	1.7	8.3	8.3	76.7	0.0	3.3	16.7	33.3	1.7	1.7	18.3	25.0	10.0
Centroptilum sp. 1	0.334	0.0	0.0	0.0	0.0	5.0	3.3	1.7	0.0	13.3	6.7	0.0	16.7	0.0	15.0	5.0	6.7
Ephemerella	0.327	0.0	0.0	0.0	8.3	8.3	0.0	0.0	0.0	8.3	0.0	10.0	0.0	1.7	8.3	26.7	1.7
Ameletus	0.301	0.0	0.0	1.7	3.3	0.0	10.0	1.7	1.7	50.0	16.7	48.3	1.7	0.0	48.3	0.0	13.3
Nematomorpha	0.277	10.0	20.0	20.0	5.0	20.0	5.0	16.7	50.0	21.7	38.3	11.7	41.7	13.3	38.3	10.0	56.7
Mean PC1 Score:		-1.470	-1.384	-1.031	-0.282	-0.175	-0.019	-0.018	0.087	0.098	0.278	0.370	0.371	0.384	0.526	0.743	1.522

PC2:

Taxon	PC Loading	Mean No./m^2 at Each Station 7W	6W	6E
Cloeon sp. 1	0.757	11.7	6.7	286.7
Cladocera	0.734	1.7	10.0	216.7
Isonychia	-0.535	0.0	13.3	0.0
Hydropsychidae	-0.533	50.0	23.3	10.0
Chironomidae	-0.490	5036.7	1961.7	885.0
Tricorythodes	-0.436	125.0	68.3	78.3
Baetis sp. X	-0.388	43.3	30.0	21.7
Heptagenia	-0.383	401.7	616.7	51.7
Ephemerella	-0.310	0.0	1.7	0.0
Oligochaeta	-0.281	2905.0	535.0	311.7
Mean PC2 Score:		-0.876	-0.810	0.995

continued . . .

Table 14. Continued.

PC3:

Taxon	PC Loading	Mean No./m² at Each Station 3E	2E	8E	1E	4E
Nematomorpha	0.769	10.0	5.0	20.0	50.0	20.0
Oligochaeta	0.691	56.7	88.3	1066.7	948.3	580.0
Baetis sp. A	0.402	10.0	0.0	0.0	33.3	8.3
Ostracoda	0.279	0.0	0.0	41.7	0.0	35.0
Chironomidae	0.269	758.3	800.0	2710.0	931.7	1593.3
Pseudocloeon	-0.473	5.0	35.0	0.0	3.3	0.0
Heptagenia	-0.301	310.0	153.3	13.3	295.0	120.0
Baetis sp. X	-0.264	1.6	13.3	1.7	8.3	1.7
Mean PC3 Score:		-1.206	-0.912	0.670	0.705	0.899

PC4:

Taxon	PC Loading	Mean No./m² at Each Station 4W	1E	3E	3W	2W	1W	2E
Ametropus	0.598	0.0	0.0	0.0	0.0	53.3	8.3	840.0
Ceratopogonidae	0.317	1.7	0.0	0.0	3.3	1.7	13.3	3.3
Hydropsychidae	-0.359	13.3	65.0	15.0	13.3	0.0	11.7	5.0
Isonychia	-0.351	83.3	90.0	31.7	125.0	3.3	15.0	8.3
Ameletus	-0.326	50.0	1.7	0.0	48.3	10.0	1.7	0.0
Ephemerella	-0.315	8.3	0.0	26.7	8.3	0.0	0.0	1.7
Cloeon sp. 1	-0.253	65.0	90.0	205.0	96.7	121.7	6.7	121.7
Mean PC4 Score:		-1.115	-0.953	-0.814	-0.792	0.610	0.641	0.965

continued . . .

Table 14. Concluded.

PC5:

Taxon	PC Loading	Mean No./m^2 at Each Station 3E	1E	5W	2E	2W	1W	6E	4E	4W	5E	3W	7E	8W	6W	8E	7W
Ostracoda	0.506	0.0	0.0	0.0	0.0	0.0	0.0	16.7	35.0	0.0	16.7	0.0	26.7	8.3	16.7	41.7	16.7
Chironomidae	0.478	758.3	931.7	575.0	803.3	800.0	973.3	885.0	1593.3	1295.0	1975.0	1490.0	1880.0	1485.0	1961.7	2710.0	1485.0
Collembola	0.388	25.0	0.0	0.0	1.7	8.3	76.7	1.7	8.3	3.3	33.3	18.3	10.0	0.0	1.7	0.0	16.7
Oligochaeta	0.337	56.7	948.3	306.7	205.0	88.3	310.0	311.7	580.0	391.7	928.3	398.3	581.7	550.0	535.0	1066.7	2905.0
Pseudocloeon	0.312	5.0	3.3	10.0	23.3	35.0	11.7	0.0	0.0	13.3	25.0	33.3	8.3	1.7	0.0	0.0	10.0
Leptophlebia	0.311	11.7	0.0	0.0	10.0	8.3	1.7	0.0	0.0	0.0	0.0	8.3	10.0	0.0	0.0	0.0	10.0
Baetis sp. A	-0.409	10.0	33.3	5.0	0.0	0.0	33.3	3.3	8.3	1.7	1.7	1.7	1.7	1.7	0.0	0.0	0.0
Isonychia	-0.369	31.7	90.0	10.0	8.3	3.3	15.0	0.0	18.3	83.3	23.3	125.0	5.0	0.0	13.3	0.0	0.0
Ametropus	-0.281	0.0	0.0	1.7	840.0	53.3	8.3	0.0	1.7	0.0	1.7	0.0	11.7	1.7	0.0	0.0	0.0
Mean PC5 Score:		-0.788	-0.760	-0.641	-0.428	-0.362	-0.284	-0.259	-0.114	-0.094	-0.059	0.092	0.316	0.338	0.530	0.707	1.806

PC6:

Taxon	PC Loading	Mean No./m^2 at Each Station 3E	6E	7E	1W
Collembola	0.478	25.0	1.7	10.0	76.7
Pseudocloeon	0.411	5.0	0.0	8.3	11.7
Ophiogomphus	0.401	5.0	10.0	20.0	20.0
Baetis sp. A	0.261	10.0	3.3	1.7	33.3
Hydropsychidae	-0.332	15.0	10.0	11.7	11.7
Ephemerella	-0.322	26.7	0.0	1.7	0.0
Ostracoda	-0.316	0.0	16.7	26.7	0.0
Mean PC6 Score:		-0.837	-0.831	-0.753	1.097

PC7:

Taxon	PC Loading	Mean No./m^2 at Each Station 3E	7E	5E	4W	2W	3W	2E
Ameletus	0.619	0.0	13.3	48.3	50.0	10.0	48.3	0.0
Ametropus	0.499	0.0	11.7	1.7	0.0	53.3	0.0	840.0
Ophiogomphus	0.304	5.0	20.0	16.7	10.0	18.3	30.0	30.0
Baetis sp. A	-0.428	10.0	1.7	1.7	1.7	0.0	1.7	0.0
Collembola	-0.274	25.0	10.0	33.3	3.3	8.3	18.3	1.7
Mean PC7 Score:		-1.505	0.301	0.476	0.510	0.575	0.622	0.719

Table 15. Principal component loadings for the first eight principal components of benthic invertebrate abundance, August samples. Loadings greater than 0.25 absolute value are printed in boldface.

Taxon	Principal Component Loadings							
	PC 1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Nematomorpha	0.213	**-0.350**	**0.369**	**0.365**	**0.324**	0.225	-0.240	-0.172
Oligochaeta	**0.487**	-0.199	**0.767**	0.197	0.015	-0.159	-0.163	0.113
Cladocera	**0.431**	**-0.320**	**-0.326**	0.025	-0.026	0.096	**0.315**	**0.555**
Ostracoda	**0.418**	**-0.472**	-0.047	0.038	**-0.260**	-0.055	-0.042	0.242
Baetis sp. C	0.097	0.025	0.198	0.164	**0.505**	0.032	-0.015	**-0.319**
Baetis sp. X	**0.528**	0.134	**-0.369**	**0.539**	-0.202	**-0.310**	-0.072	-0.057
Centroptilum sp. 1	0.037	0.041	-0.159	-0.057	-0.131	-0.107	**0.380**	0.063
Cloeon sp. 1	**0.537**	**-0.306**	-0.207	**-0.450**	0.083	-0.155	**-0.251**	0.175
Pseudocloeon	0.129	-0.156	-0.214	**0.358**	**0.470**	-0.078	-0.187	**-0.285**
Heptagenia	**0.622**	0.139	**-0.370**	0.009	0.104	**0.268**	-0.081	-0.193
Ametropus	**0.368**	**0.547**	0.037	-0.237	-0.220	**-0.375**	**0.326**	-0.201
Metretopus	0.194	**0.283**	-0.072	**-0.361**	**-0.331**	-0.084	-0.097	**-0.339**
Leptophlebia	0.219	**-0.524**	**-0.463**	**0.302**	0.033	0.031	-0.217	0.101
Tricorythodes	**0.560**	-0.164	-0.144	-0.209	**0.314**	**-0.413**	0.192	**-0.341**
Caenis	**0.279**	**0.312**	-0.060	-0.201	-0.215	**-0.310**	**0.260**	-0.087

continued ....

Table 15. Concluded.

Taxon	Principal Component Loadings							
	PC 1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Ophiogomphus	**0.367**	-0.069	**-0.445**	-0.017	**0.333**	0.204	**0.352**	0.051
Perlodidae	**0.396**	**0.700**	-0.009	**0.353**	-0.096	**0.337**	0.114	0.067
Neureclipsis	**0.285**	**-0.472**	-0.188	-0.136	**0.263**	**0.305**	**0.394**	-0.159
Hydropsychidae	**0.458**	**0.678**	0.052	-0.116	**0.304**	-0.048	**-0.303**	0.186
Oecetis	0.219	-0.136	-0.053	0.190	0.206	**0.342**	**0.269**	-0.225
Ceratopogonidae	**0.563**	-0.247	0.001	-0.080	**-0.556**	**0.275**	-0.162	**-0.274**
Chironomidae	0.102	**-0.527**	**0.443**	0.157	-0.143	-0.194	**-0.346**	-0.050
Empididae	**0.499**	0.048	**0.336**	**-0.486**	-0.007	**0.384**	-0.037	-0.022

Table 16. Benthic invertebrate taxa with the highest absolute PC loadings (at least 0.25), August samples. Principal component scores are determined primarily by the log (no./m^2 + 1) of these taxa.

PC1:	*Heptagenia*	0.622			
	Ceratopogonidae	0.563			
	Tricorythodes	0.560			
	Cloeon sp. 1	0.537			
	Baetis sp. X	0.528			
	Empididae	0.499			
	Oligochaeta	0.487			
	Hydropsychidae	0.458			
	Cladocera	0.431			
	Ostracoda	0.418			
	Perlodidae	0.396			
	Ametropus	0.368			
	Ophiogomphus	0.367			
	Neureclipsis	0.285			
	Caenis	0.279			
PC2:	Perlodidae	0.700	vs.	Chironomidae	-0.527
	Hydropsychidae	0.678		*Leptophlebia*	-0.524
	Ametropus	0.547		*Neureclipsis*	-0.472
	Caenis	0.312		Ostracoda	-0.472
	Metretopus	0.283		Nematomorpha	-0.350
				Cladocera	-0.320
				Cloeon sp. 1	-0.306

continued ....

Table 16. Continued.

PC3:	Oligochaeta	0.767	vs.	*Leptophlebia*	-0.463
	Chironomidae	0.443		*Ophiogomphus*	-0.445
	Nematomorpha	0.369		*Heptagenia*	-0.370
	Empididae	0.336		*Baetis* sp. X	-0.369
				Cladocera	-0.326
PC4:	*Baetis* sp. X	0.539	vs.	Empididae	-0.486
	Nematomorpha	0.365		*Cloen* sp. 1	-0.450
	Pseudocloeon	0.358		*Metretopus*	-0.361
	Perlodidae	0.353			
	Leptophlebia	0.302			
PC5:	*Baetis* sp. C	0.505	vs.	Ceratopogonidae	-0.556
	Pseudocloeon	0.470		*Metretopus*	-0.331
	Ophiogromphus	0.333		Ostracoda	-0.260
	Nematomorpha	0.324			
	Tricorythodes	0.314			
	Hydropsychidae	0.304			
	Neureclipsis	0.263			
PC6:	Empididae	0.384		*Tricorythodes*	-0.413
	Oecetis	0.342		*Ametropus*	-0.375
	Perlodidae	0.337		*Baetis* sp. X	-0.310
	Neureclipsis	0.305		*Caenis*	-0.310
	Ceratopogonidae	0.275			
	Heptagenia	0.268			

continued ....

Table 16. Concluded.

PC7:	*Neureclipsis*	0.394	vs.	Chironomidae	-0.346
	Centroptilum sp. 1	0.380		Hydropsychidae	-0.303
	Ophiogomphus	0.352		*Cloeon* sp. 1	-0.251
	Ametropus	0.326			
	Cladocera	0.315			
	Oecetis	0.269			
	Caenis	0.260			
PC8:	Cladocera	0.555	vs.	*Tricorythodes*	-0.341
				Metretopus	-0.339
				Baetis sp. C	-0.319
				Pseudocloeon	-0.285
				Ceratopogonidae	-0.274

Table 17. Analysis of variance of benthic invertebrate principal component scores at the 16 sampling stations, August samples.

	Between Stations			Error			
Principal Component	Degrees of Freedom	Sum of Squares	Mean Squares	Degrees of Freedom	Sum of Squares	Mean Squares	F
PC1	15	29.051	1.937	32	17.949	0.561	3.45**
PC2	15	35.924	2.395	32	11.076	0.346	6.92***
PC3	15	29.803	1.987	32	17.197	0.537	3.70***
PC4	15	29.479	1.972	32	17.421	0.544	3.62**
PC5	15	20.196	1.346	32	26.804	0.838	1.61
PC6	15	31.769	2.118	32	15.231	0.476	4.45***
PC7	15	19.903	1.327	32	27.098	0.847	1.57
PC8	15	18.408	1.227	32	28.592	0.894	1.37

** significant with $P < 0.01$

*** significant with $P < 0.001$

Table 18. Results of Student - Newman - Keuls multiple comparisons tests of benthic invertebrate principal component scores at each sampling station, August samples. Significant differences are indicated by the lines below the mean PC scores. Stations joined by the same line are not significantly different (P > 0.5) from each other. Only stations that were significantly different from at least one other station are included. Abundances of taxa with the highest loadings (at least 0.25 absolute value) on each PC are included in the upper part of each table section.

PC1:

Taxon	PC Loading	Mean No./m^2 at Each Station 8E	5W	7W	8W	7E	4E
Heptagenia	0.622	3.3	100.0	120.0	116.7	386.7	360.0
Ceratopogonidae	0.563	3.3	6.7	0.0	0.0	30.0	70.0
Tricorythodes	0.560	0.0	16.7	0.0	0.0	60.0	46.7
Cloeon sp.1	0.537	0.0	60.0	3.3	16.7	173.3	70.0
Baetis sp. X	0.528	3.3	0.0	120.0	3.3	83.3	113.3
Empididae	0.499	0.0	16.7	0.0	6.7	3.3	36.7
Oligochaeta	0.487	860.0	0.0	6.6	313.3	220.0	400.0
Hydropsychidae	0.458	0.0	63.3	66.7	60.0	3.3	243.3
Cladocera	0.431	0.0	0.0	0.0	0.0	70.0	33.3
Ostracoda	0.418	0.0	0.0	0.0	0.0	66.7	0.0
Perlodidae	0.396	0.0	16.7	13.3	16.7	0.0	86.7
Ametropus	0.368	0.0	3.3	0.0	3.3	0.0	76.7
Ophiogomphus	0.367	0.0	26.7	23.3	6.7	66.7	20.0
Neureclipsis	0.285	0.0	6.7	0.0	0.0	26.7	0.0
Caenis	0.279	0.0	0.0	0.0	0.0	0.0	13.3
Mean PC1 Score:		-1.667	-0.895	-0.825	-0.636	0.935	1.737

continued . . .

Table 18. Continued.

PC2:

Taxon	PC Loading	Mean No./m^2 at Each Station 7E	6E	2W	8E	5E	6W	2E	3W	8W	4W	5W	1W	1E	7W	3E	4E
Perlodidae	0.700	0.0	6.7	16.7	0.0	10.0	26.7	23.3	150.0	16.7	140.0	16.7	83.3	200.0	13.3	43.3	86.7
Hydropsychidae	0.678	3.3	46.7	0.0	0.0	36.7	33.3	56.7	16.7	60.0	16.7	63.3	66.7	103.3	66.7	76.7	243.3
Ametropus	0.547	0.0	0.0	3.3	0.0	3.3	0.0	3.3	6.7	3.3	0.0	3.3	3.3	3.3	0.0	40.0	76.7
Caenis	0.312	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	13.3
Metretopus	0.283	0.0	0.0	6.7	0.0	0.0	3.3	3.3	0.0	0.0	0.0	6.7	0.0	0.0	0.0	6.7	16.7
Chironomidae	-0.527	2953.3	793.3	1536.7	5970.0	1093.3	2233.3	1563.3	560.0	1070.0	1230.0	493.3	106.7	1050.0	1410.0	590.0	840.0
Leptophlebia	-0.524	63.3	33.3	6.7	0.0	10.0	6.7	23.3	23.3	0.0	0.0	0.0	0.0	0.0	10.0	3.3	0.0
Neureclipsis	-0.472	26.7	36.7	10.0	0.0	3.3	3.3	3.3	10.0	0.0	0.0	6.7	3.3	0.0	0.0	0.0	0.0
Ostracoda	-0.472	66.7	16.7	16.7	0.0	0.0	0.0	66.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	0.0
Nematomorpha	-0.350	3.3	60.0	3.3	6.7	20.0	33.3	16.7	6.7	3.3	13.3	0.0	0.0	26.7	0.0	0.0	0.0
Cladocera	-0.320	70.0	16.7	16.7	0.0	0.0	70.0	0.0	16.7	0.0	0.0	0.0	23.3	0.0	0.0	0.0	33.3
Cloeon sp. 1	-0.306	173.3	10.0	56.7	0.0	43.3	36.7	10.0	0.0	16.7	0.0	60.0	6.7	26.7	3.3	33.3	70.0
Mean PC2 Score:		-2.01	-1.00	-0.978	-0.795	-0.472	-0.438	-0.280	0.182	0.296	0.471	0.548	0.664	0.778	0.789	1.076	1.171

PC3:

Taxon	PC Loading	Mean No./m^2 at Each Station 7E	7W	5W	3W	1E	8W	8E
Oligochaeta	0.767	220.0	6.7	0.0	80.0	326.7	313.3	860.0
Chironomidae	0.443	2953.3	1410.0	493.3	560.0	1050.0	1070.0	5970.0
Nematomorpha	0.369	3.3	0.0	0.0	6.7	26.7	3.3	6.7
Empididae	0.336	3.3	0.0	16.7	3.3	20.0	6.7	0.0
Leptophlebia	-0.463	63.3	10.0	0.0	23.3	0.0	0.0	0.0
Ophiogomphus	-0.445	66.7	23.3	26.7	30.0	13.3	6.7	0.0
Heptagenia	-0.370	386.7	120.0	100.0	380.0	293.3	116.7	3.3
Baetis sp. X	-0.369	83.3	120.0	0.0	60.0	33.3	3.3	3.3
Cladocera	-0.326	70.0	0.0	0.0	16.7	0.0	0.0	0.0
Mean PC3 Score:		-1.393	-0.962	-0.784	-0.740	0.958	1.113	1.654

continued . . .

Table 18. Concluded.

PC4:

Taxon	PC Loading	Mean No./m^2 at Each Station 5W	4E	6W	7W	3W	4W
Baetis sp. X	0.539	0.0	113.3	3.3	120.0	60.0	56.7
Nematomorpha	0.365	0.0	0.0	33.3	0.0	6.6	13.3
Pseudocloeon	0.358	0.0	0.0	0.0	3.3	3.3	10.0
Perlodidae	0.353	16.7	86.7	26.7	13.3	150.0	140.0
Leptophlebia	0.302	0.0	0.0	6.7	10.0	23.3	0.0
Empididae	-0.486	16.7	36.7	86.7	0.0	3.3	0.0
Cloeon sp. 1	-0.450	60.0	70.0	36.7	3.3	0.0	0.0
Metretopus	-0.361	6.7	16.7	3.3	0.0	0.0	0.0
Mean PC4 Score:		-1.631	-0.954	-0.929	0.792	1.378	1.525

PC6:

Taxon	PC Loading	Mean No./m^2 at Each Station 3E	8E	4E	5E	7E	1W	3W	6W
Empididae	0.384	16.7	0.0	36.7	0.0	3.3	20.0	3.3	86.7
Oecetis	0.342	0.0	0.0	0.0	0.0	10.0	0.0	30.0	3.3
Perlodidae	0.337	43.3	0.0	86.7	10.0	0.0	83.3	150.0	26.7
Neureclipsis	0.305	0.0	0.0	0.0	3.3	26.7	3.3	10.0	3.3
Ceratopogonidae	0.275	30.0	3.3	70.0	13.3	30.0	3.3	46.7	33.3
Heptagenia	0.268	206.7	3.3	360.0	230.0	386.7	93.3	380.0	320.0
Tricorythodes	-0.413	23.3	0.0	46.7	33.3	60.0	0.0	6.6	0.0
Ametropus	-0.375	40.0	0.0	76.7	3.3	0.0	3.3	6.7	0.0
Baetis sp. X	-0.310	66.7	3.3	113.3	40.0	83.3	26.7	60.0	3.3
Caenis	-0.310	6.7	0.0	13.3	0.0	0.0	0.0	0.0	0.0
Mean PC6 Score:		-1.273	-1.091	-1.070	-0.961	-0.695	0.798	1.244	1.331

3.2.5 Summary of Benthic Invertebrate Analyses

Is is clear from Tables 6, 10, 14, and 18 that most stations differed significantly from others at lease once with respect to at least one principal component. In the discussion to follow, however, only those differences are discussed that may be attributable to (1) Fort McMurray sewage discharge, (2) Clearwater River influences and (3) Suncor plant effluent (i.e., Station 7 is compared with Station 8, and Station 4 is compared with Station 5). It must be remembered throughout that differences also may be simply artifacts of the sample selection method used.

3.2.5.1 Stations 7E, 7W, 8E, and 8W. Stations 8E and 8W are controls above the influences of Fort McMurray and the Clearwater River. Station 7E is within the plume of the Clearwater River, and Station 7W is thought to be influenced by the Fort McMurray sewage treatment plant effluent (Boerger 1983).

No differences in the benthic invertebrate principal components for these stations were detectable in May (Table 6); however several significant differences were detected among the stations in the June data (PC2 and PC4; Table 10). Station 7W had a significantly higher June PC2 score than 8E, primarily because of higher numbers of Heptagenia at 7W. Station 7W did not differ significantly from Station 8W with respect to June PC2, but Station 7E had a significantly higher PC2 score than both stations 8E and 8W. The difference was largely due to greater numbers of certain Ephemeroptera (Heptagenia, Baetis sp. A, Metretopus, Pseudocloeon) and fewer Oligachaeta at Station 7E. Station 7E did have a significantly higher June PC4 score than Station 7W, primarily because of the much greater abundance of Caenis at Station 7E.

In July, differences among the four stations were confined to PC1 and PC5 (Table 14). Stations 7E and 7W had higher PC1 values than stations 8E and 8W, principally because certain Ephemeroptera (especially Caenis, Tricorythodes, and Heptagenia) and (in the case of Station 7E) Cladocera and Cloeon were more abundant at the two downstream stations. Station 7W had a much higher PC5 score than the other three stations because of its abundant population of Oligochaeta.

More differences among the benthic invertebrate associations of the four stations were found in August, with respect to PC1, PC2, and PC3 scores (Table 18). Station 7E had a significantly higher PC1 score than Station 8E, primarily because of the greater numbers of certain Ephemeroptera (especially *Heptagenia*, *Tricorythodes*, *Cloeon* sp. 1, and *Baetis* sp. X), Ceratopogonidae, Cladocera, Ostracoda, *Ophiogomphus*, and *Neureclipsis*. Station 7E also had a lower August PC2 score than stations 8W and 7W. The difference was caused mainly by the low numbers of Perlodidae and Hydropsychidae and the greater numbers of Oligochaeta, *Leptophlebia*, *Neureclipsis*, Ostracoda, Cladocera, and *Cloeon* sp. 1 at Station 7E. Finally, stations 7E and 7W both had lower August PC3 scores than stations 8E and 8W, mostly due to various combinations of lower numbers of Oligochaeta and/or Chironomidae and higher numbers of various positive-loading taxa at Stations 7E and 7W.

It is interesting to note that stations 8E and 8W did not differ significantly from each other with respect to the 31 principal components of the benthic invertebrate abundance data over the entire study period. It would appear that these stations are sufficiently alike in their benthic invertebrate associations that either or both could serve as control sites.

Station 7W, thought to be influenced by Fort McMurray sewage discharge (Boerger 1983), might be expected to show evidence of enrichment such as increased abundances of algae-eating invertebrates. This in fact did account for differences between certain principal component scores at Station 7W and the control stations. Most of the Ephemeroptera (except *Metretopus*, thought to be predaceous by Merritt and Cummins 1978), whose greater abundance at Station 7W accounted for certain significantly higher principal component scores there, are at least partly algae-scrapers (Merritt and Cummins 1978). However, some evidence is inconsistent. Station 7W had a significantly increased July PC5 score primarily because of high numbers of Oligochaeta there. The situation was reversed in

August, when very low numbers of Oligochaeta at Station 7W gave it a PC3 score significantly lower than that at one of the control stations.

Station 7E, in the Clearwater River plume, differed from the control stations with regard to several of the principal components. Some, but not all, of the differences were due principally to higher numbers of certain taxa at Station 7E that are characteristic of slow-flowing or even lentic environments, such as Caenis, Metretopus, Cladocera, Cloeon, Ceratopogonidae, Neureclipsis, and Leptophlebia (Merritt and Cummins 1978; Pennak 1978). Water velocity at Station 7E was not clearly slower than at least one of the control stations (Boerger 1983). It is possible that numbers of these characteristically lentic or slow-water groups were contributed by drift out of the Clearwater River.

3.2.5.2 Stations 4E, 4W, 5E, and 5W. Stations 5E and 5W are located a short distance upstream of the Suncor development, and were evidently intended to act as control sites. Unfortunately, as Boerger (1983) has pointed out, there are no suitable control sites upstream of Suncor because waters from the Clearwater River and the Athabasca River flow separately and unmixed past 5E and 5W until the river is forced into a sharp turn by the embankment at the upstream end of the Suncor site. Presumably, benthic invertebrate associations at Station 5E reflect the influence of Clearwater water, and those at Station 5W reflect conditions in the Athabasca water. In fact, the two control stations differed significantly with respect to three principal components of the benthic invertebrate data (May PC3, June PC4, and July PC1; Tables 6, 10 and 14, respectively). Invertebrate associations at stations 4E and 4W, on the other hand, reflect the influence of the mixed Clearwater and Athabasca water as well as the influence of the Suncor plant, if any. In addition, Station 5W is located downstream from Poplar Creek, through which saline mine depressurization water from Syncrude Canada Ltd. is discharged.

None of the 31 principal components examined showed significant differences between either of the Station 4 sites and both the control sites (Tables 6, 10, 14, and 18). To this extent, there is no evidence that Suncor operations have had a catastrophic effect on the river macrobenthos.

3.3 RELATIONSHIPS BETWEEN WATER QUALITY AND BENTHIC INVERTEBRATES

In 1981, water quality data were collected for only five of the eight benthic sampling stations (stations 1, 2, 3, 6, and 8). Examination of correlations between water quality and benthic invertebrates is therefore limited to these five stations. The results of correlation analyses of benthic invertebrate principal component scores and water quality principal component scores are presented in Table 19. Fourteen correlation coefficients were found to be significant at $P < 0.05$, 11 were significant at $P < 0.01$, and 12 were significant at $P < 0.001$.

In the discussion to follow, only correlations significant at $P < 0.001$ are considered. The large number of individual analyses (6 water quality PCs and 31 benthos PCs give 186 correlation coefficients) could lead to a number of false correlations being accepted if a significance level of 0.05 were adopted. Furthermore, it is unclear to what extent the benthic invertebrate sample selection technique used by Boerger (1983) would affect the correlation analyses (see Section 3.2). It was felt that, in view of these limitations, it was appropriate to consider only those correlations significant at $P < 0.001$, recognizing that even these might be spurious.

In May, the only significant ($P < 0.001$) correlations were between benthos PC6 and water quality PC2 and PC5. Benthos PC6 is primarily a measure of the abundance of Empididae, Perlodidae, and Simuliidae (Table 4), and was positively correlated with water quality PC2 and negatively correlated with water quality PC5. Water quality PC2 represents non-filterable residue, total phosphate, and several metals, while PC5 represents primarily dissolved orthophosphate (Table 2).

Water quality PCs 2 and 5 also were correlated with benthos PCs in June. Water quality PC2 was negatively correlated with ben-

Table 19. Correlations between benthic invertebrate principal component scores and water quality principal component scores in 1981. Sample sizes are 30 for May, 60 for June and July, and 30 for August.

May:

Benthos Principal Component	Water Quality Principal Component	Correlation Coefficient (R)	R^2	Significance
PC1	PC6	0.398	0.158	$P < 0.05$
PC2	PC3	0.383	0.147	$P < 0.05$
PC5	PC1	-0.465	0.216	$P < 0.01$
	PC2	-0.435	0.189	$P < 0.05$
	PC4	0.386	0.149	$P < 0.05$
	PC5	0.506	0.256	$P < 0.01$
PC6	PC1	0.570	0.325	$P < 0.01$
	PC2	0.573	0.328	$P < 0.001$
	PC4	-0.513	0.263	$P < 0.01$
	PC5	-0.657	0.432	$P < 0.001$

June:

Benthos Principal Component	Water Quality Principal Component	Correlation Coefficient (R)	R^2	Significance
PC1	PC2	-0.502	0.252	$P < 0.001$
	PC3	-0.480	0.230	$P < 0.001$
	PC4	0.631	0.398	$P < 0.001$
	PC5	-0.383	0.147	$P < 0.01$
	PC6	-0.301	0.090	$P < 0.05$
PC2	PC4	0.260	0.068	$P < 0.05$
PC3	PC5	-0.450	0.202	$P < 0.001$
PC4	PC4	0.428	0.183	$P < 0.001$
PC5	PC1	0.270	0.073	$P < 0.05$
	PC3	0.341	0.116	$P < 0.01$

continued . . .

Table 19. Concluded.

July:

Benthos Principal Component	Water Quality Principal Component	Correlation Coefficient (R)	R^2	Significance
PC1	PC1	-0.437	0.191	$P < 0.001$
	PC2	-0.768	0.590	$P < 0.001$
	PC3	0.455	0.207	$P < 0.001$
	PC4	0.364	0.133	$P < 0.01$
	PC5	0.330	0.109	$P < 0.05$
PC2	PC3	-0.585	0.343	$P < 0.001$
PC3	PC1	0.369	0.136	$P < 0.01$
	PC5	0.316	0.100	$P < 0.05$
PC5	PC2	0.545	0.297	$P < 0.001$
	PC3	-0.344	0.118	$P < 0.01$
	PC5	-0.342	0.117	$P < 0.01$
PC6	PC6	0.362	0.131	$P < 0.01$
PC7	PC6	-0.303	0.092	$P < 0.05$

August:

Benthos Principal Component	Water Quality Principal Component	Correlation Coefficient (R)	R^2	Significance
PC1	PC4	0.462	0.213	$P < 0.05$
PC6	PC1	0.431	0.186	$P < 0.05$
	PC2	0.386	0.149	$P < 0.05$
PC8	PC5	0.394	0.155	$P < 0.05$

thos PC1 and water quality PC5 was negatively correlated with benthos PC3. Benthos PC1 in June represents a relatively large number of benthic taxa, most of which are positively loading, but is primarily a measure of Chironomidae, *Tricorythodes*, *Caenis*, *Isonychia*, *Heptagenia*, *Cloeon* sp.1, Oligochaeta, and *Ophiogomphus* (Table 8). Benthos PC3 represents Oligochaeta, *Baetis* sp. A, and Simuliidae, which are positively loading taxa, as well as *Ameletus*, *Cloeon* sp. 1, and *Caenis*, which have negative loadings. There were also significant correlations between benthos PC1 and water quality PCs 3 and 4; a negative correlation with PC3; and a positive correlation with PC4. Water quality PC3 is a measure of potassium, copper, zinc, and lead, while PC4 represents primarily sodium, chloride, and ammonia. Benthos PC4 in June, which represents Ceratopogonidae, *Caenis*, *Brachycercus*, and *Ophiogomphus* (with positive loadings) and Hydropsychidae, *Ameletus*, and *Heptagenia* (with negative loadings), was correlated positively with water quality PC4.

In July, water quality PC1, which represents dissolved solids, was negatively correlated with benthos PC1. Benthos PC1 represents primarily the abundance of *Caenis*, *Tricorythodes*, *Heptagenia*, *Ophiogomphus*, *Isonychia*, Cladocera, *Cloeon* sp. 1, and Collembola, all of which are positively loading taxa (Table 12). Water quality PC2 (non-filterable residue, total phosphate, and some metals) was also negatively correlated with benthos PC1, and water quality PC3 (potassium, copper, zinc, and lead) was positively correlated with benthos PC1. Water quality PC2 was positively correlated with benthos PC5, and water quality PC3 was negatively correlated with benthos PC2. Benthos PC5 in July is a measure of Ostracoda, Chironomidae, and Collembola (positively loading) and *Baetis* sp. A and *Isonychia* (negatively loading). Benthos PC2 represents primarily *Cloeon* sp. 1 and Cladocera (with positive loadings) and *Isonychia*, Hydropsychidae, Chironomidae, *Tricorythodes*, *Baetis* sp. X, and *Heptagenia* (with negative loadings).

With some exceptions, water quality principal components 1, 2, 4, and 5, which accounted for 9 of the 12 correlations significant at $P < 0.001$, show consistent differences between left and right banks of the Athabasca River (Figures 10 to 15). These differences are evidence that tributary waters entering on the right bank of the Athabasca, especially the Clearwater River, do not fully mix with mainstream waters through much of the study area. The benthos PCs correlated with water quality PCs 1, 2, 4, and 5 may reflect the influence only of drift and colonization of invertebrates within this discrete water mass, rather than any direct influence of the chemical constituents themselves.

Water quality PC3 shows no consistent difference between right and left banks of the Athasbasca River (Figure 13). It is not clear what the significant correlations ($P < 0.001$) between this principal component and three benthos PCs means. Water chemistry PC3 scores are influenced most strongly by concentrations of lead, potassium, zinc, and copper. Lead, zinc, and especially copper, can be toxic to aquatic life, so high PC3 scores would be expected to correlate negatively with positively loading elements of benthic invertebrate principal components. In at least one case, however, there was a positive correlation (with benthos PC1 in July). Therefore, toxic effects would seem to be ruled out. There is no clear explanation for the correlations with water quality PC3.

4. CONCLUSIONS

There are strong correlations apparent among several of the water quality parameters considered in the present study. Most of the major ions (calcium, magnesium, sodium, chloride, sulphate, and bicarbonate) are strongly correlated with each other and with specific conductance, total alkalinity, and filterable residue. Potassium concentrations, however, appear to be independent of the concentrations of other major ions. There are also components of sodium and chloride, attributable to the Clearwater River and other east bank tributaries, that are not strongly related to the concentrations of other ions. All of the metals except lead and mercury are strongly associated with non-filterable residue and total phosphate. There is also some suggestion, however, that there may be components of zinc and copper that are not associated with non-filterable residue.

With respect to those water quality parameters included in the present study, there is no evidence that effluent from the Suncor plant has a large or consistent effect on the water quality of the Athabasca River downstream from the development. The suggestion is that any effects on water quality are short-term in nature and have not resulted in changes that persist for long periods of time.

The major differences in water quality within the study area are between the left and right sides of the Athabasca River downstream from Fort McMurray. These differences are attributable primarily to the influences of the Clearwater River and other right bank tributaries, and involve mainly sodium and chloride concentrations.

There are some differences in benthic invertebrate abundance and community composition within the study area that appear to be related to nutrient enrichment due to Fort McMurray sewage effluent (see Section 3.2.5.1). There is no evidence of large differences in benthic invertebrate populations between stations immediately upstream and downstream of the Suncor development that can be attributed to the Suncor effluent. Most of the observed differences in benthic invertebrate abundance or community composition are differences between the left and right sides of the Athabasca River, and are probably due to the influences of right bank tributaries and, at least for several kilometres downstream from Fort McMurray, to the effects of effluent from the sewage treatment plant.

The abundance of a variety of benthic invertebrate taxa appears to be correlated with several water quality parameters. In most cases, these correlations are with water quality parameters that show differences between the left and right sides of the Athabasca River. The observed correlations therefore may be due to drifting of, and colonization by, invertebrates from the Clearwater River, and possibly, other right bank tributaries, rather than to any direct influence of water quality.

The results of analysis of benthic invertebrate data presented in this report should be considered tentative or inconclusive. The method used for selecting benthic samples adversely affects the validity of statistical analyses (see Section 3.2), and the reliability of the results is therefore questionable.

5. RECOMMENDATIONS

Within the group of 29 water quality parameters examined in detail in the present study, there would appear to be few opportunities to limit the number of parameters measured to a smaller group and still adequately characterize water quality. The ions of calcium, magnesium, sulphate, and bicarbonate are all strongly correlated with each other and with specific conductance, total alkalinity, and filterable residue. It may not be necessary, therefore, to obtain measurements on all of these parameters. In particular, specific conductance, total alkalinity, and filterable residue would appear to provide little information in addition to that already provided by measurements of other parameters.

The pattern of correlations observed for measurements of nitrogen, phosphate, and organic carbon suggest that continued measurement of all these would be appropriate. Similarly, phenolic material and oil and grease are largely independent of other parameters and of each other, and they also should be measured in future water quality monitoring.

Although there are strong correlations among most of the metals (except lead and mercury), the results of two principal component analyses (see sections 3.1.1 and 3.1.2) are not entirely consistent in this regard. It would not appear practical, at the present time, to use measurements of some of the metals as indicators of the probable levels of other metals.

The number of water quality monitoring stations and their locations in the study area would appear, for the most part, to be adequate for the present level of development in the area. One additional station, downstream from Fort McMurray but closer to the city, probably would be useful. Sampling at monthly intervals, which has usually been the schedule used, appears to be generally adequate if only continuous effluent discharges are involved, but more frequent sampling during periods of rapid change would seem desirable. If the application of multivariate statistical methods is anticipated, it is important that all water quality parameters are determined for all samples.

When benthic invertebrates are sampled for the purposes of a monitoring study, and when the effluent discharges of interest are continuous, three sampling periods during the year (early spring, mid-summer, and fall) should be sufficient. Many closely spaced sampling intervals are not particularly useful unless a precise description of seasonal changes is required. In general, it would be better to reduce the number of sampling periods and increase the sample sizes. Sample sizes of three, although common in benthic invertebrate studies, are minimal, and it is unlikely that less than catastrophic changes in benthic populations would be detectable with such a small number of replicate samples. It is essential, for the valid application of statistical methods, that random sampling procedures be employed when collecting benthic invertebrate samples.

For the purposes of examining relationships between benthic invertebrates and water quality, it would be desirable to conduct a study at a location where a range of water quality conditions exists and where possible relationships are not confounded to a great extent by the effects of drift and colonization of benthos from major tributaries to the stream being studied. Benthic populations in tributary streams may be quite different for a variety of reasons unrelated to water quality. In addition, it is clear that where benthic invertebrate populations may be influenced by water quality, the influence takes place over a period of time and is not constant during this time. Water quality measurements taken at the same time as benthic samples may not be particularly relevant in terms of the observed benthic populations. An alternative approach, that might be more informative, would be to integrate water quality measurements over some period of time prior to sampling benthic invertebrates. These integrated values would then be used as an indication of the water quality conditions to which a particular site had been exposed previously. This approach would require regular monitoring of water quality for a period of time prior to the sampling of benthic invertebrates. It is suggested that, at least as a first guess, a time period of one full year in advance of benthic sampling may be appropriate.

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7. APPENDICES

7.1 WATER QUALITY DATA, 1976 to 1983

Figures 16 to 83 include plots of 68 water quality parameters measured at seven stations on the Athabasca River for the years 1976 through 1983. The determination of location in the river channel was based on distances to the left and right banks (looking downstream) as recorded in the NAQUADAT data files. Samples located anywhere within the left 34% of the river width were considered left bank samples, those within the right 34% were considered right bank samples, and those within the central 32% were considered mid-channel samples. For 105 of the 538 water samples, there was insufficient information in the NAQUADAT files to determine sampling location. These samples were assumed to be mid-channel samples. Curves on the graphs were interrupted whenever the time period between samples was greater than four months.

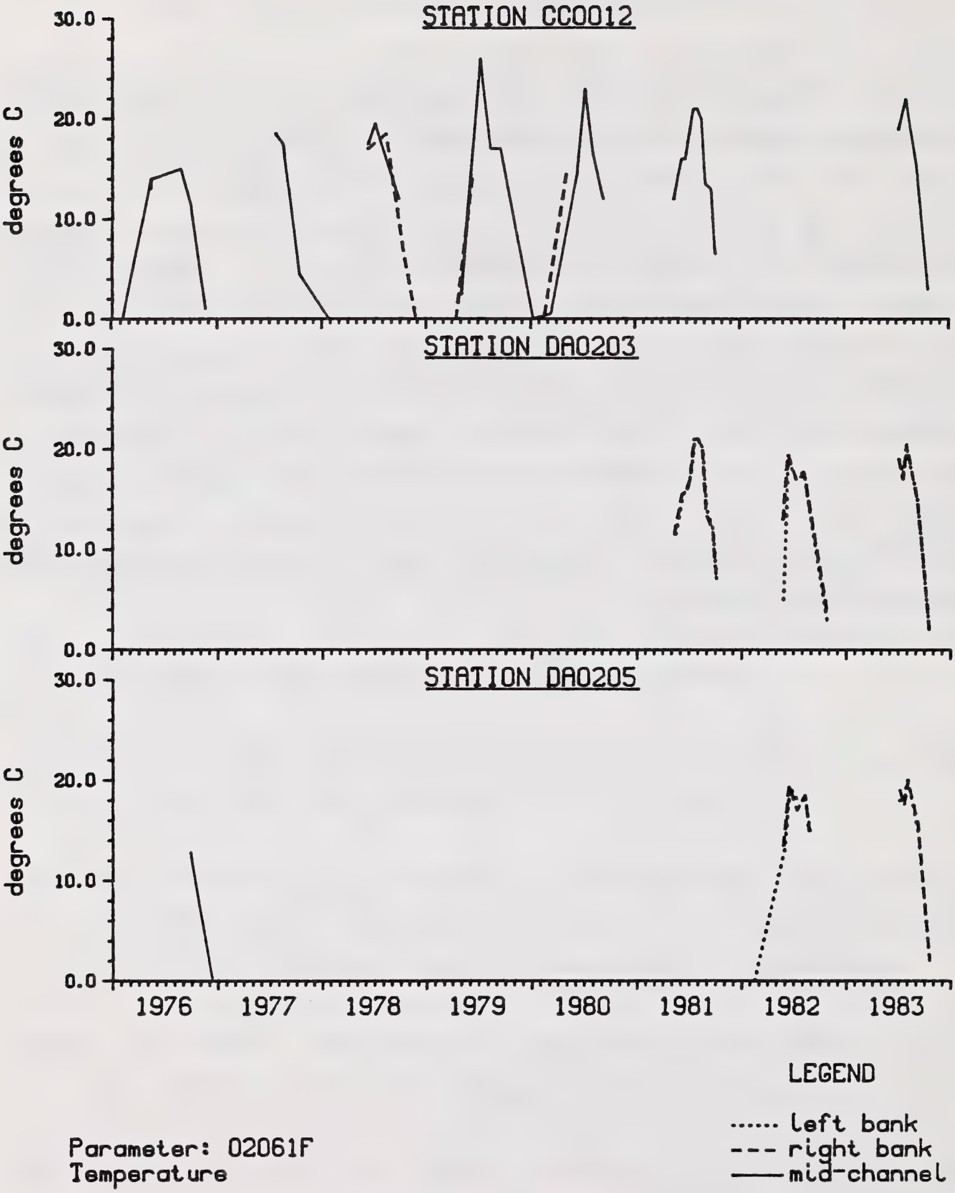

Figure 16. Water temperature at seven stations on the Athabasca River from 1976 to 1983.

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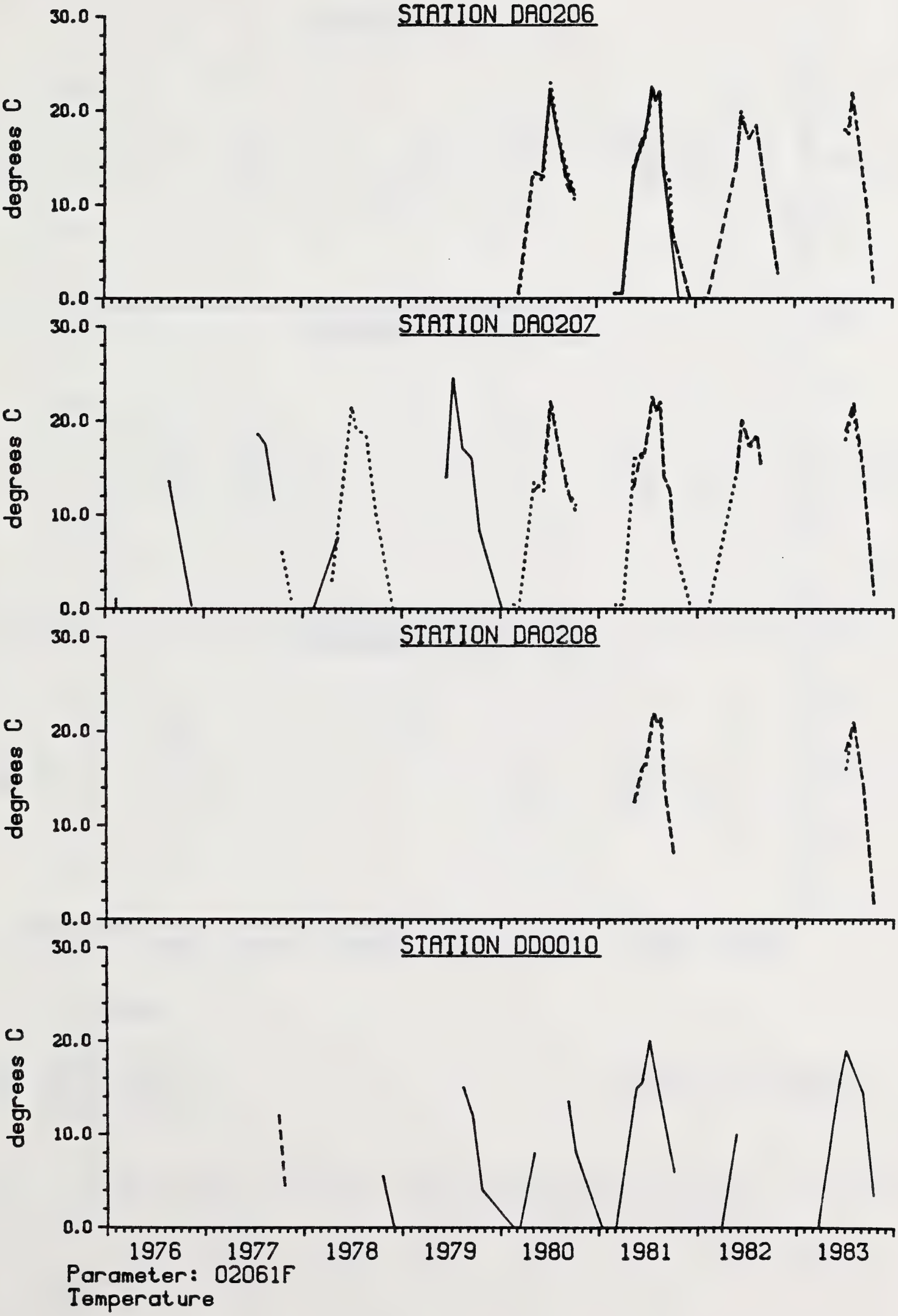

Figure 16. Concluded.

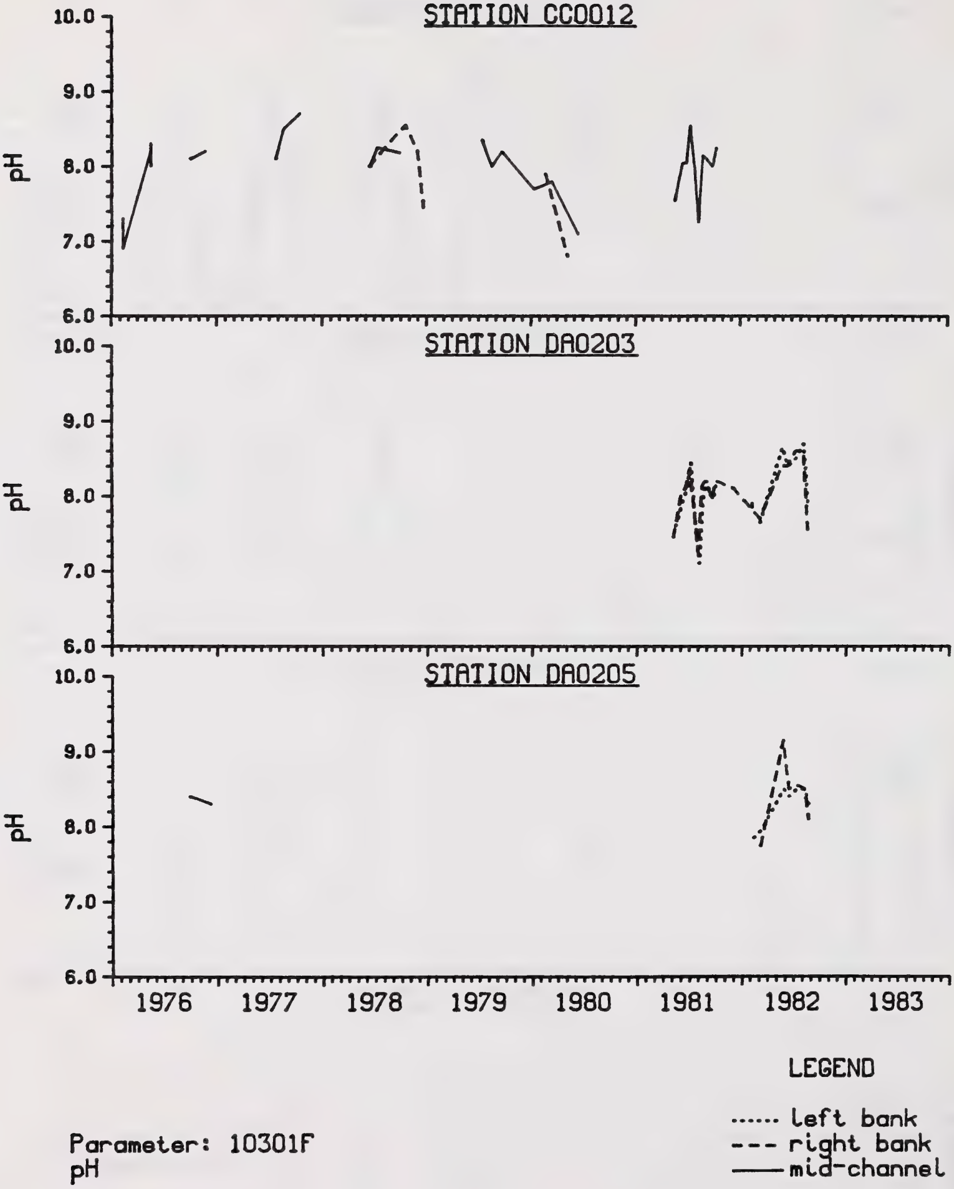

Figure 17. Field-measured pH at seven stations on the Athabasca River from 1976 to 1983.

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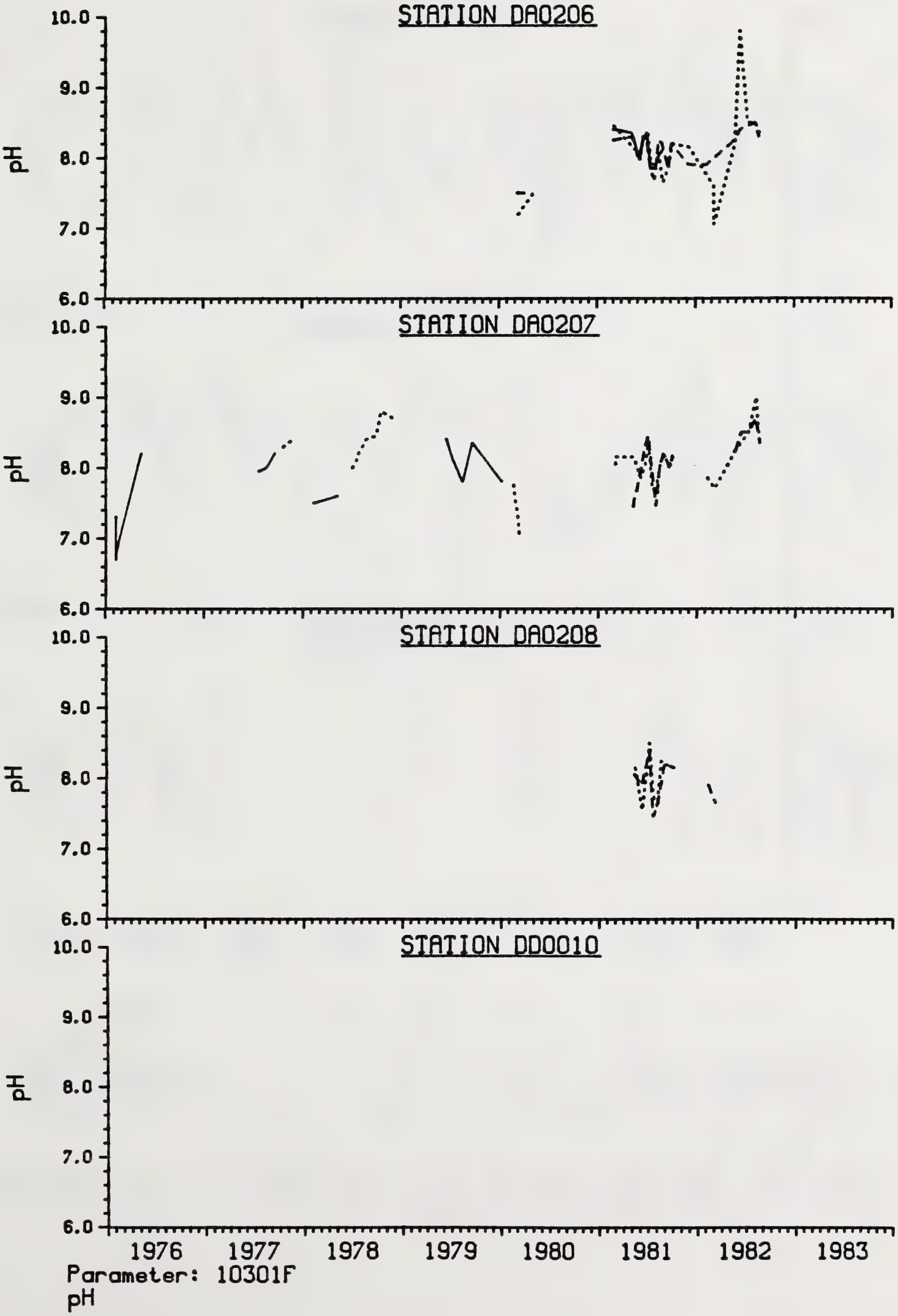

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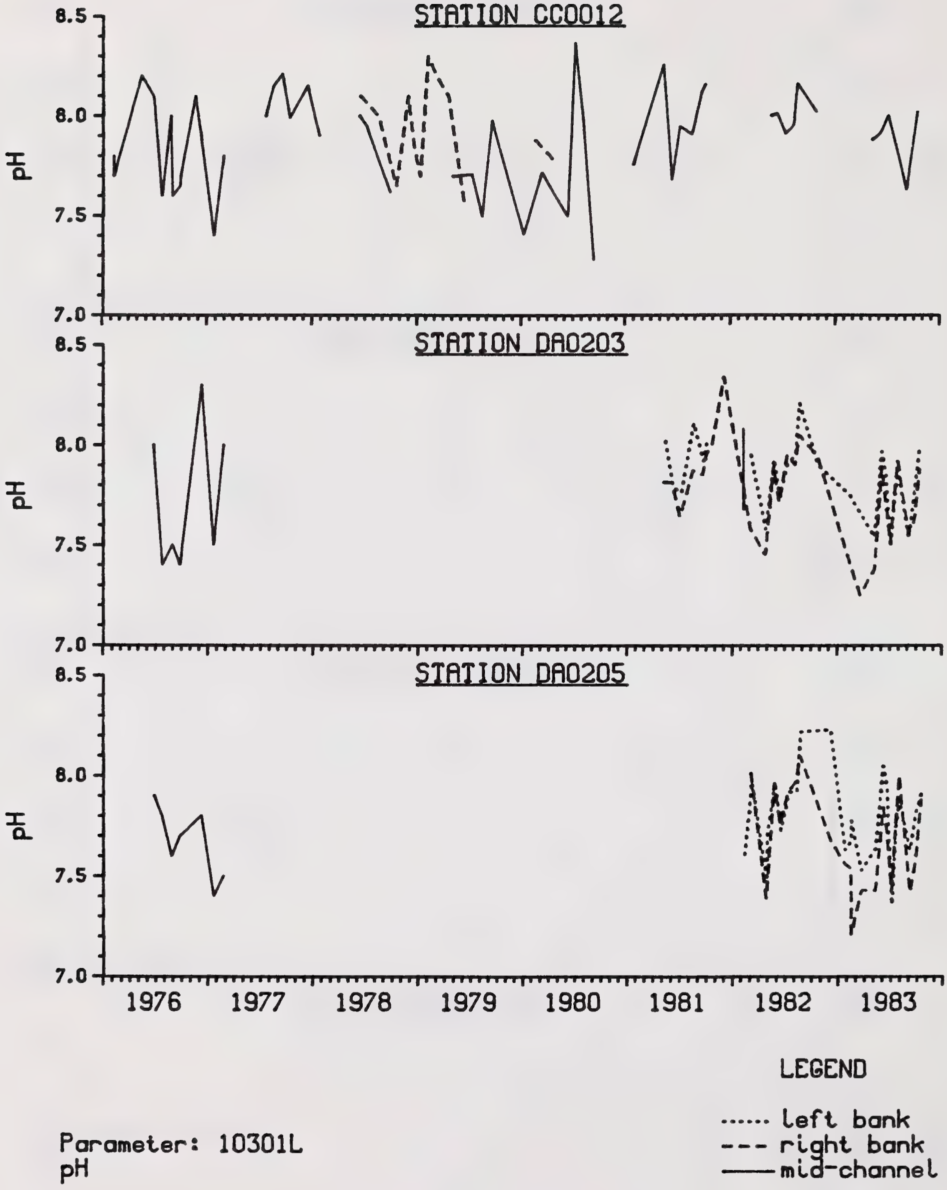

Figure 18. Laboratory-measured pH at seven stations on the Athabasca River from 1976 to 1983.

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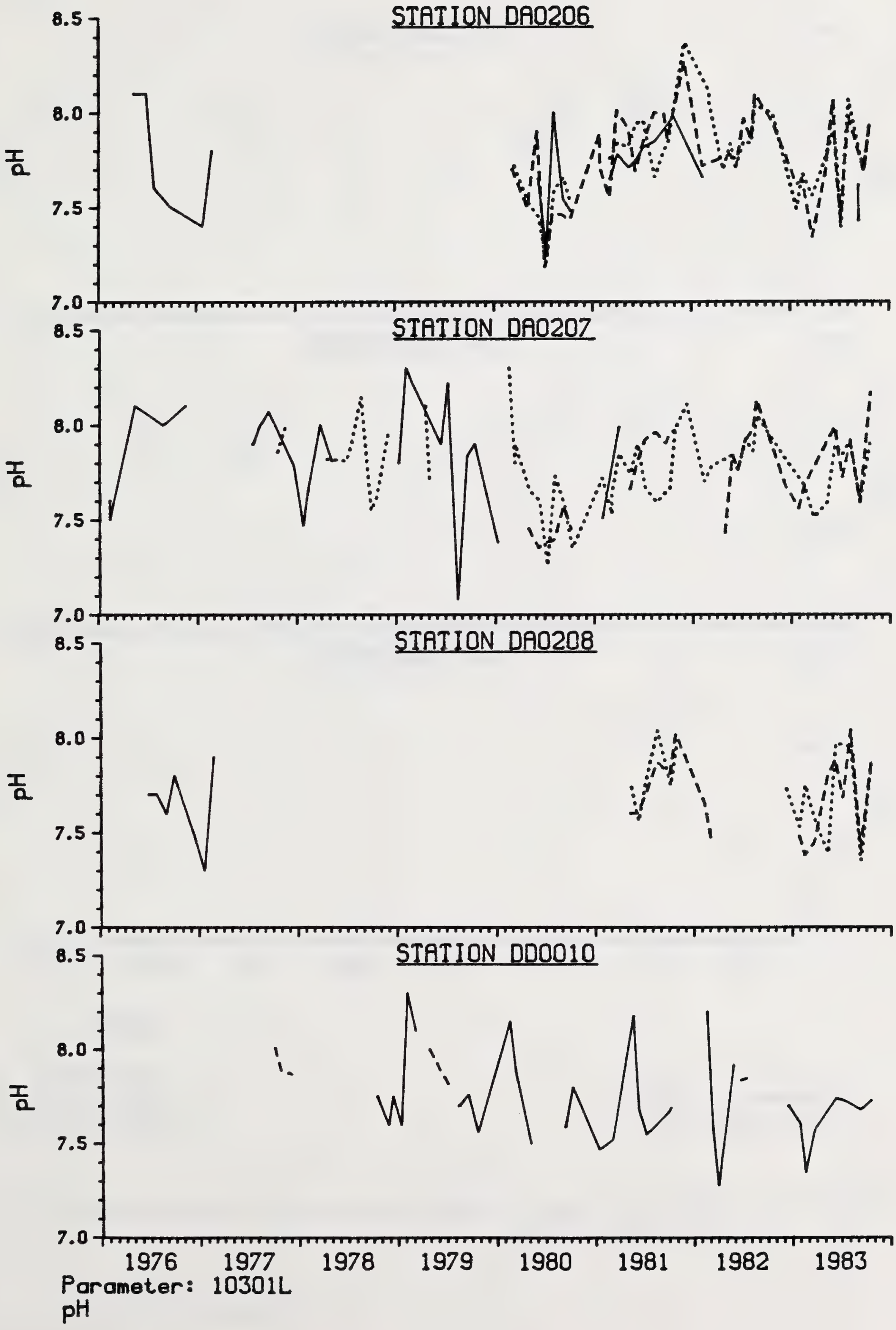

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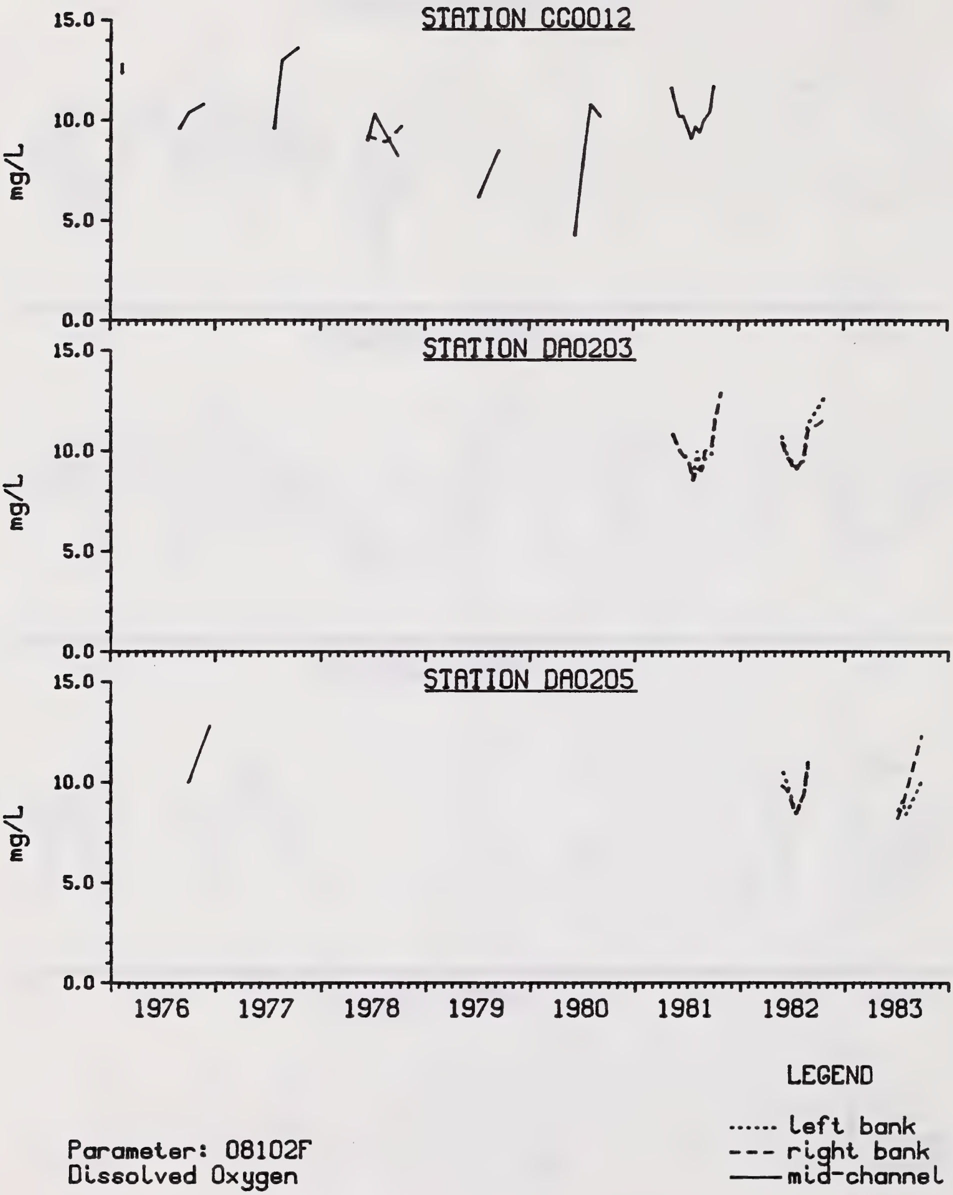

Figure 19. Dissolved oxygen at seven stations on the Athabasca River from 1976 to 1983.

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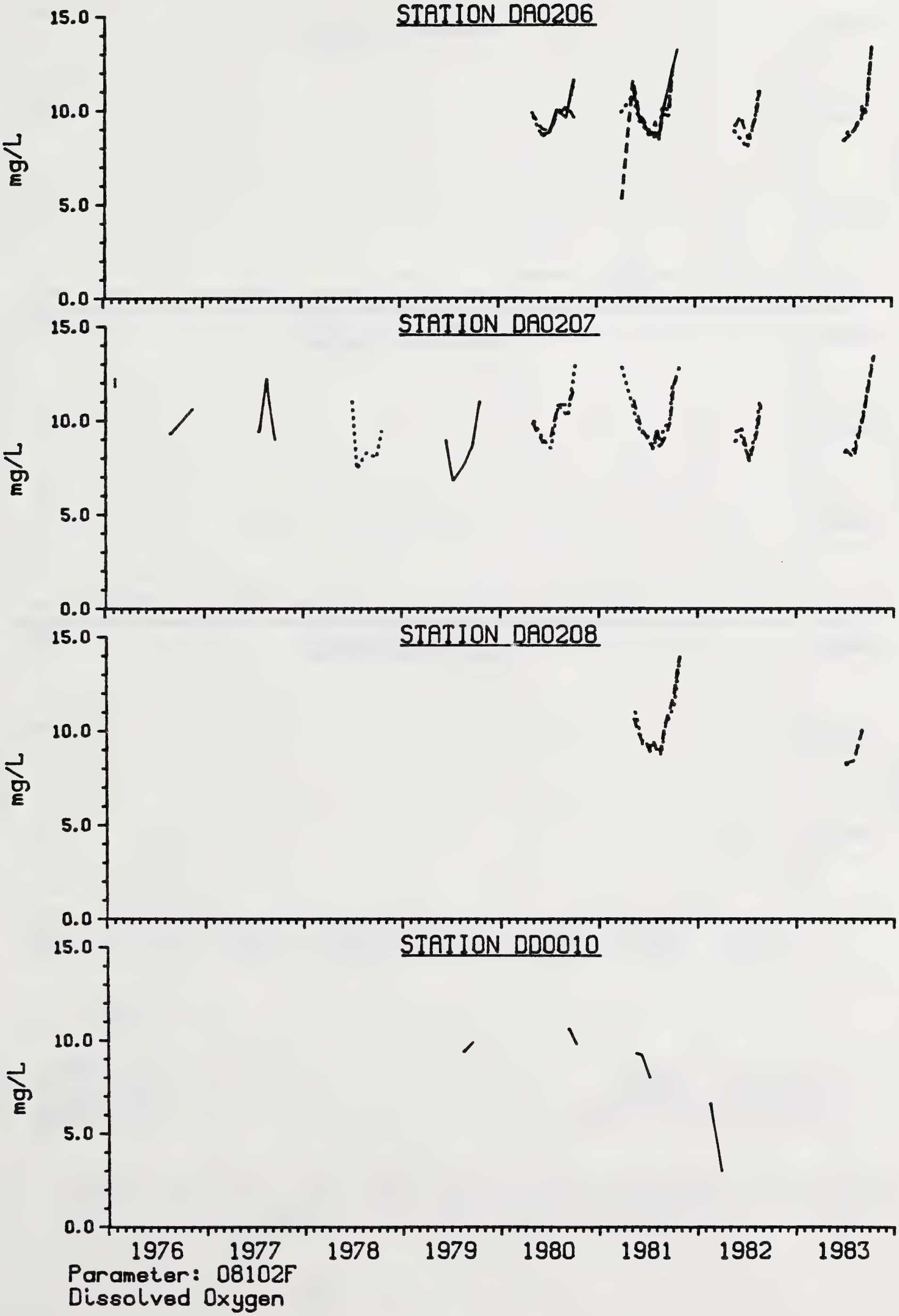

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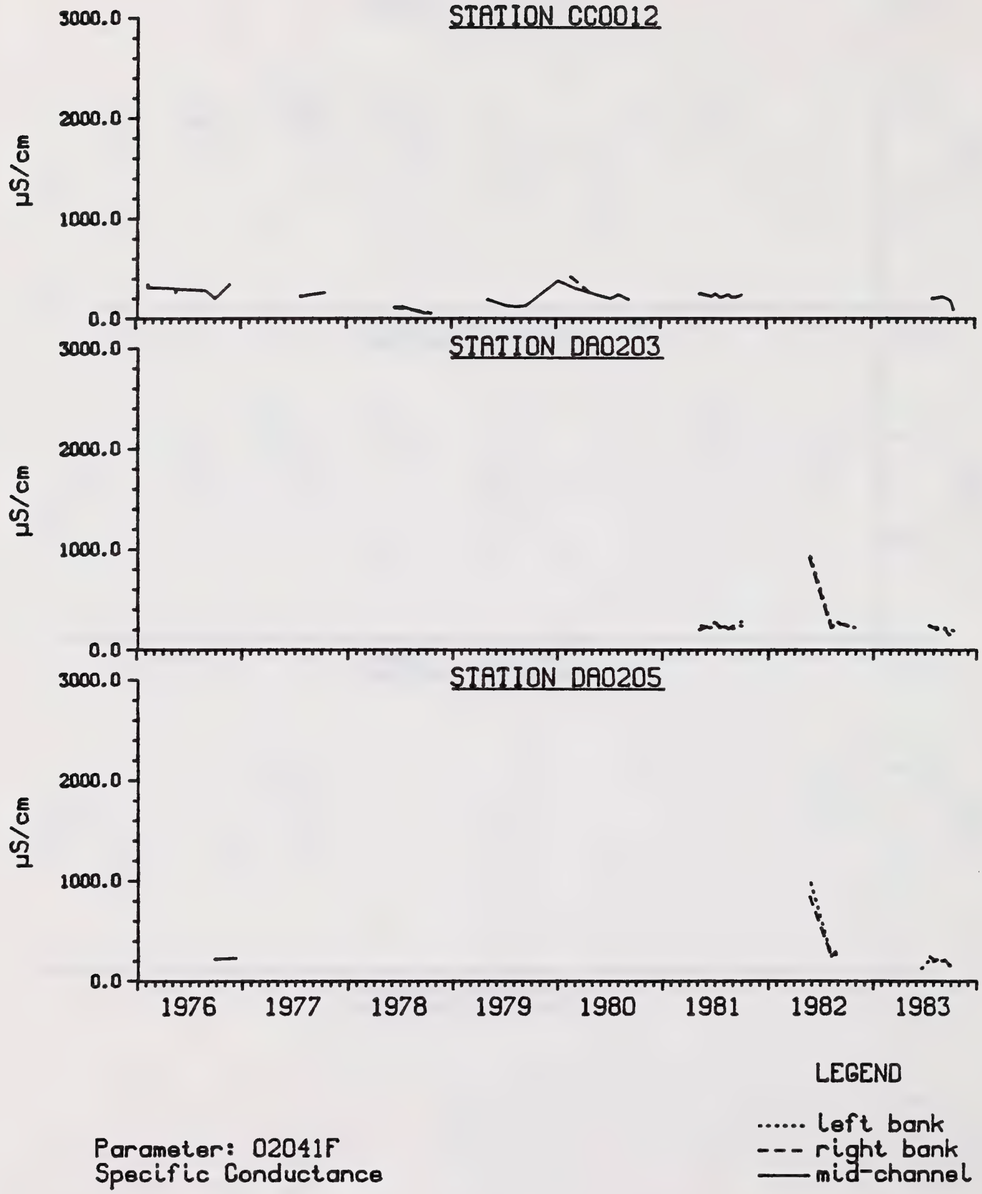

Figure 20. Field-measured specific conductance at seven stations on the Athabasca River from 1976 to 1983.

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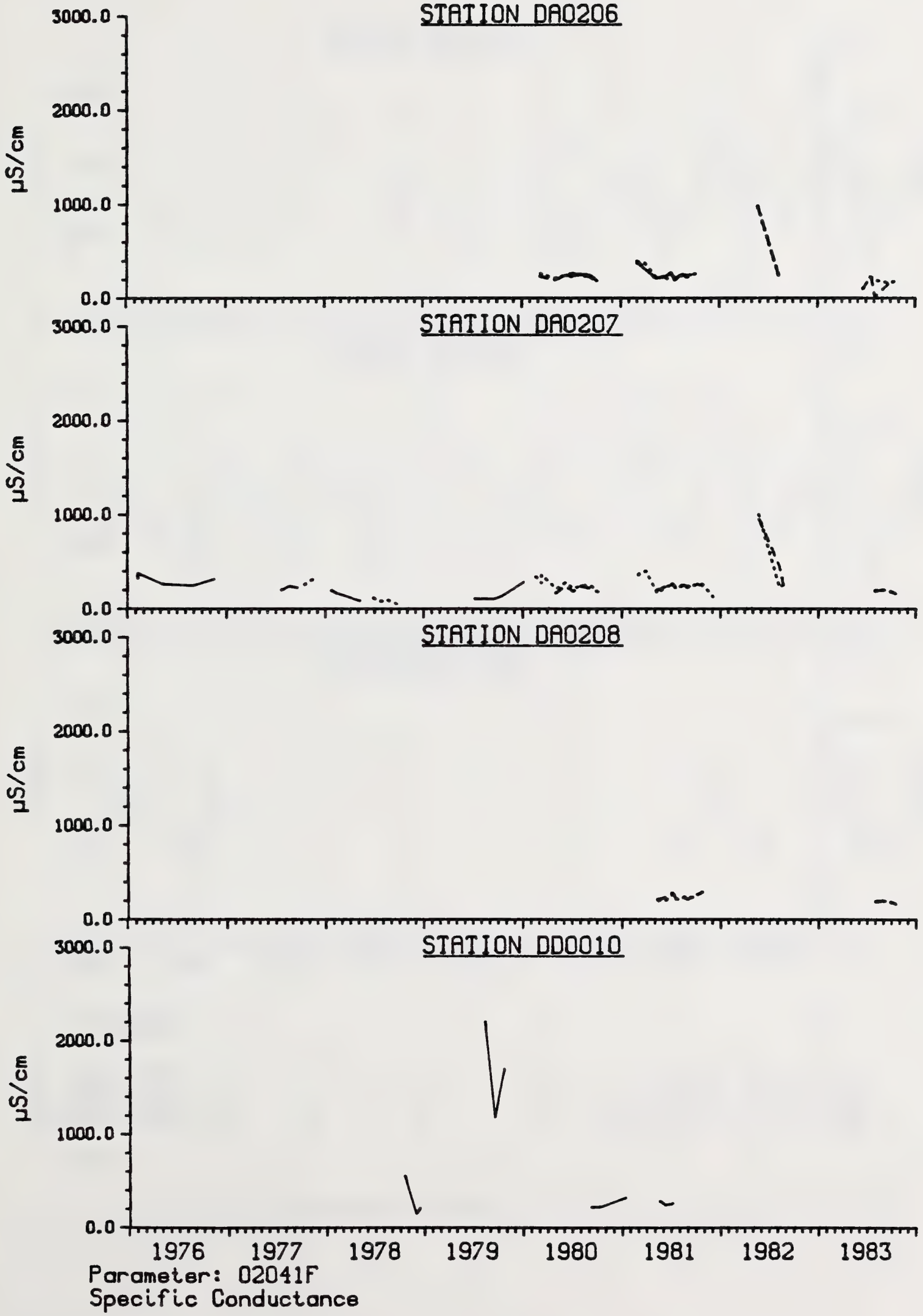

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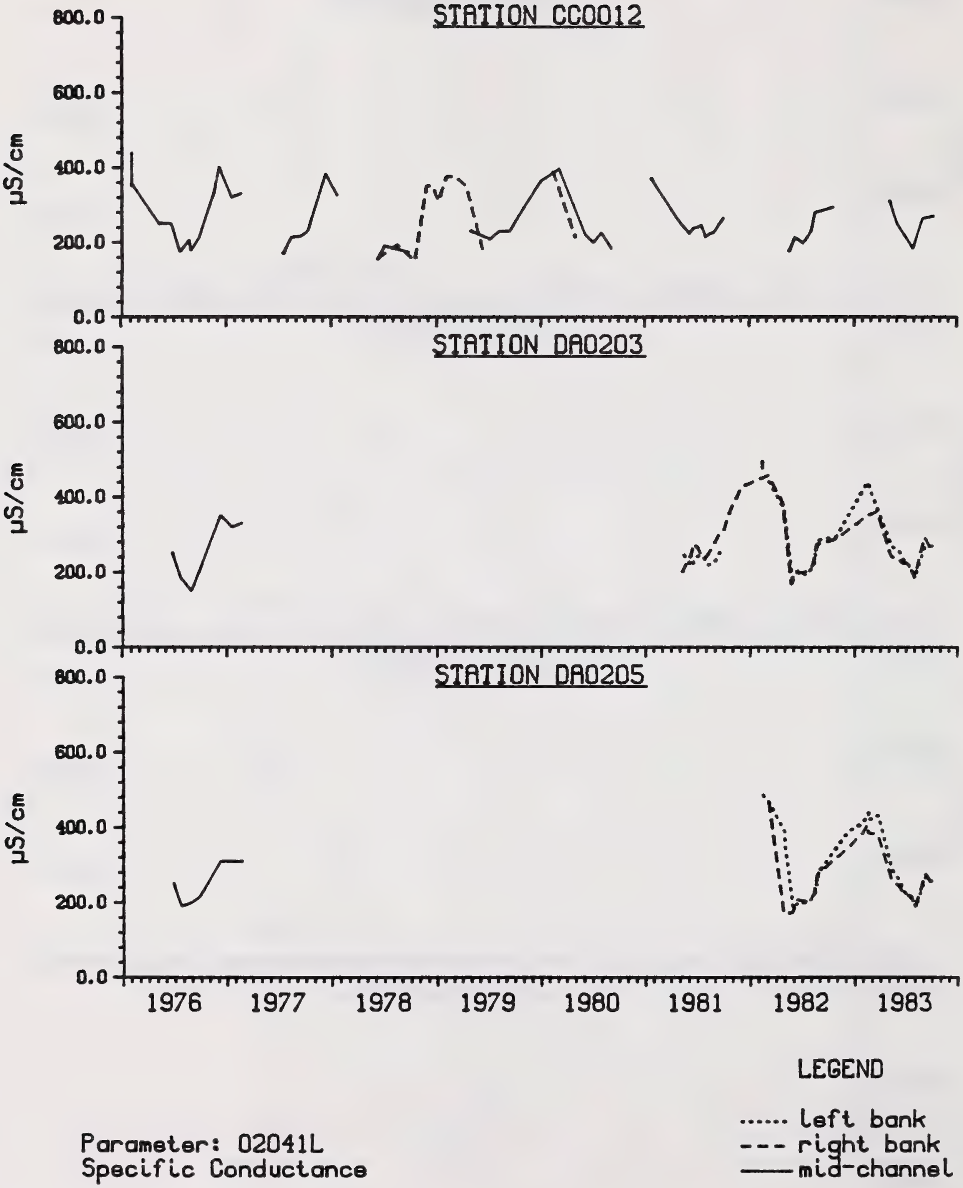

Figure 21. Laboratory-measured specific conductance at seven stations on the Athabasca River from 1976 to 1983.

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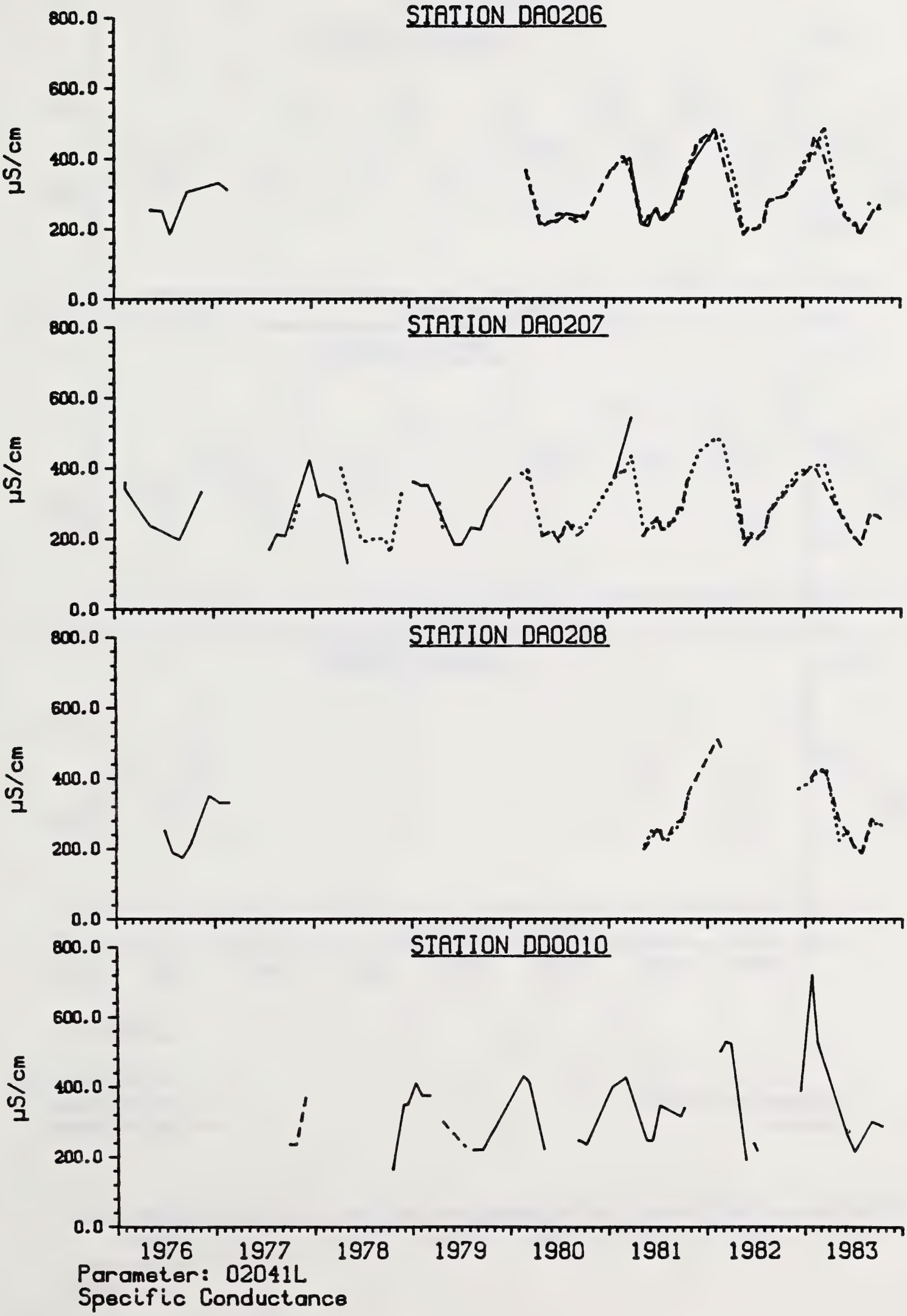

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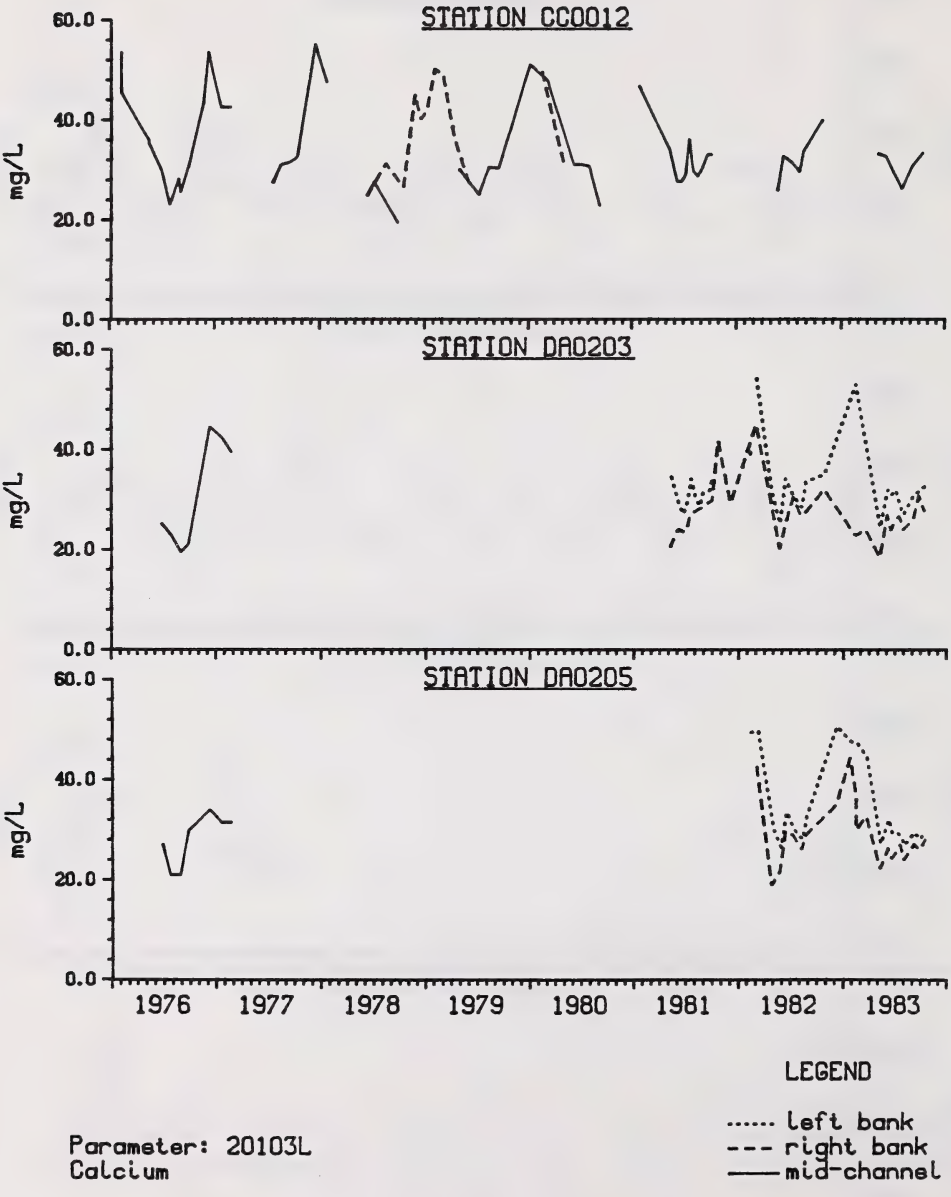

Figure 22. Calcium at seven stations on the Athabasca River from 1976 to 1983.

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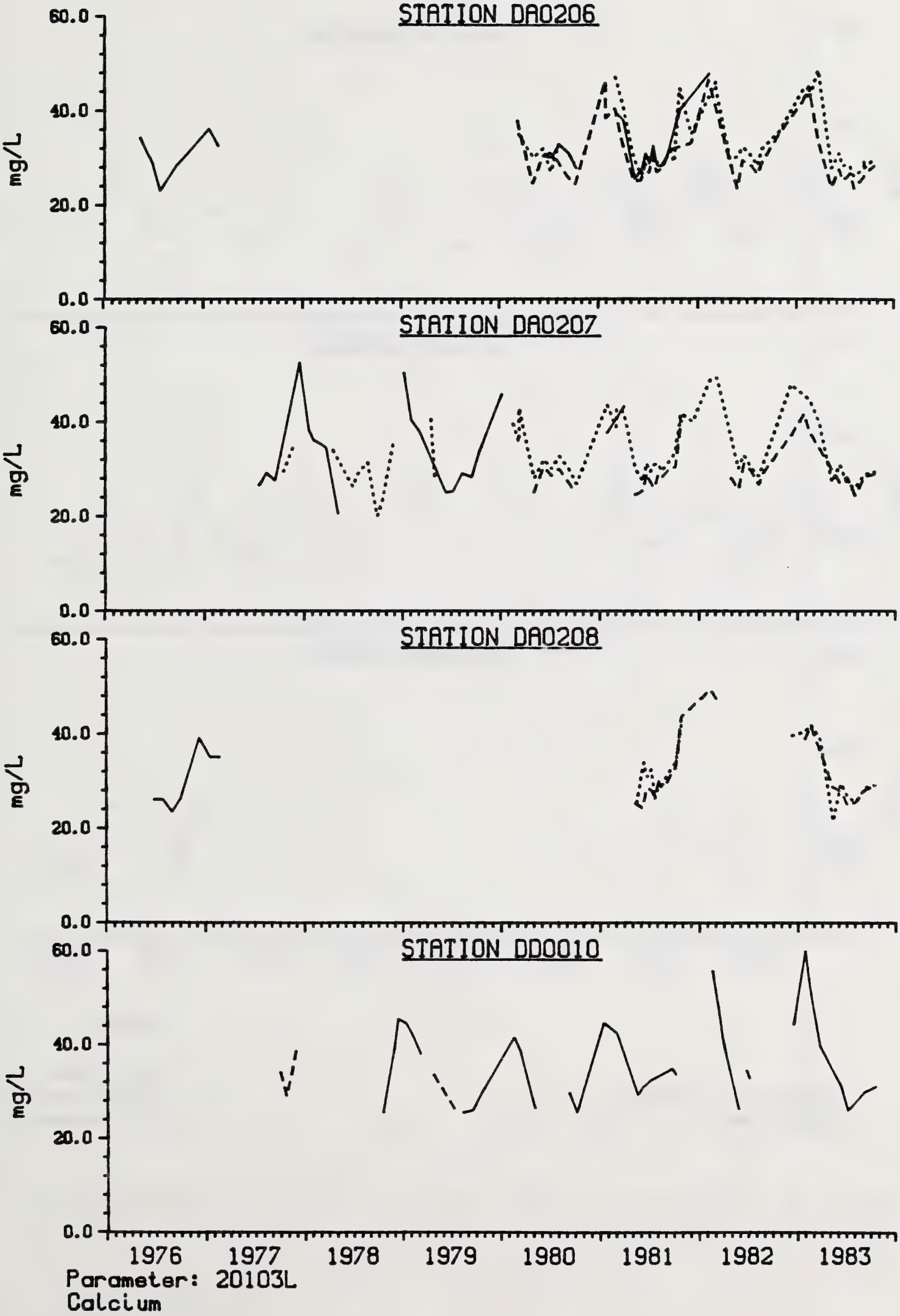

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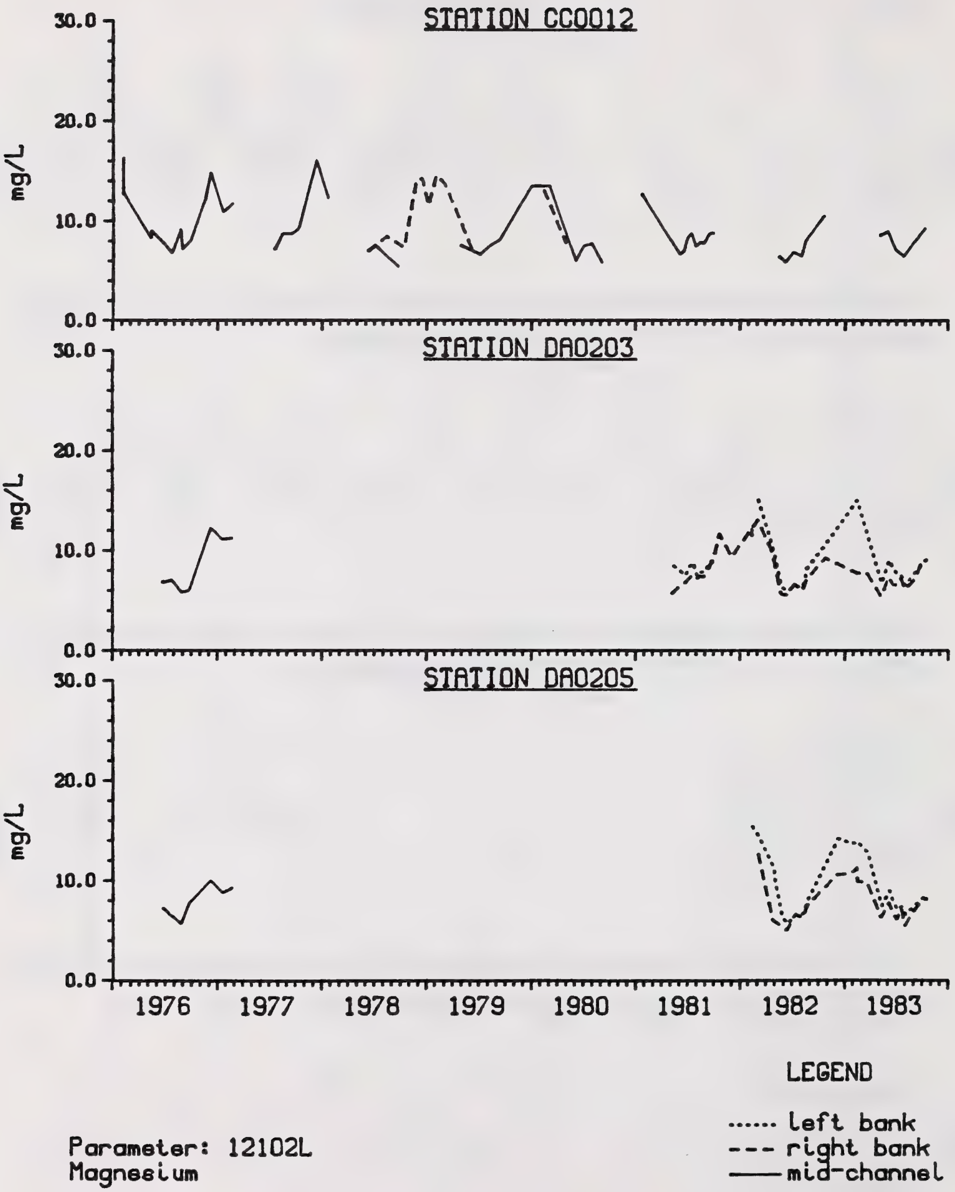

Figure 23. Magnesium at seven stations on the Athabasca River from 1976 to 1983.

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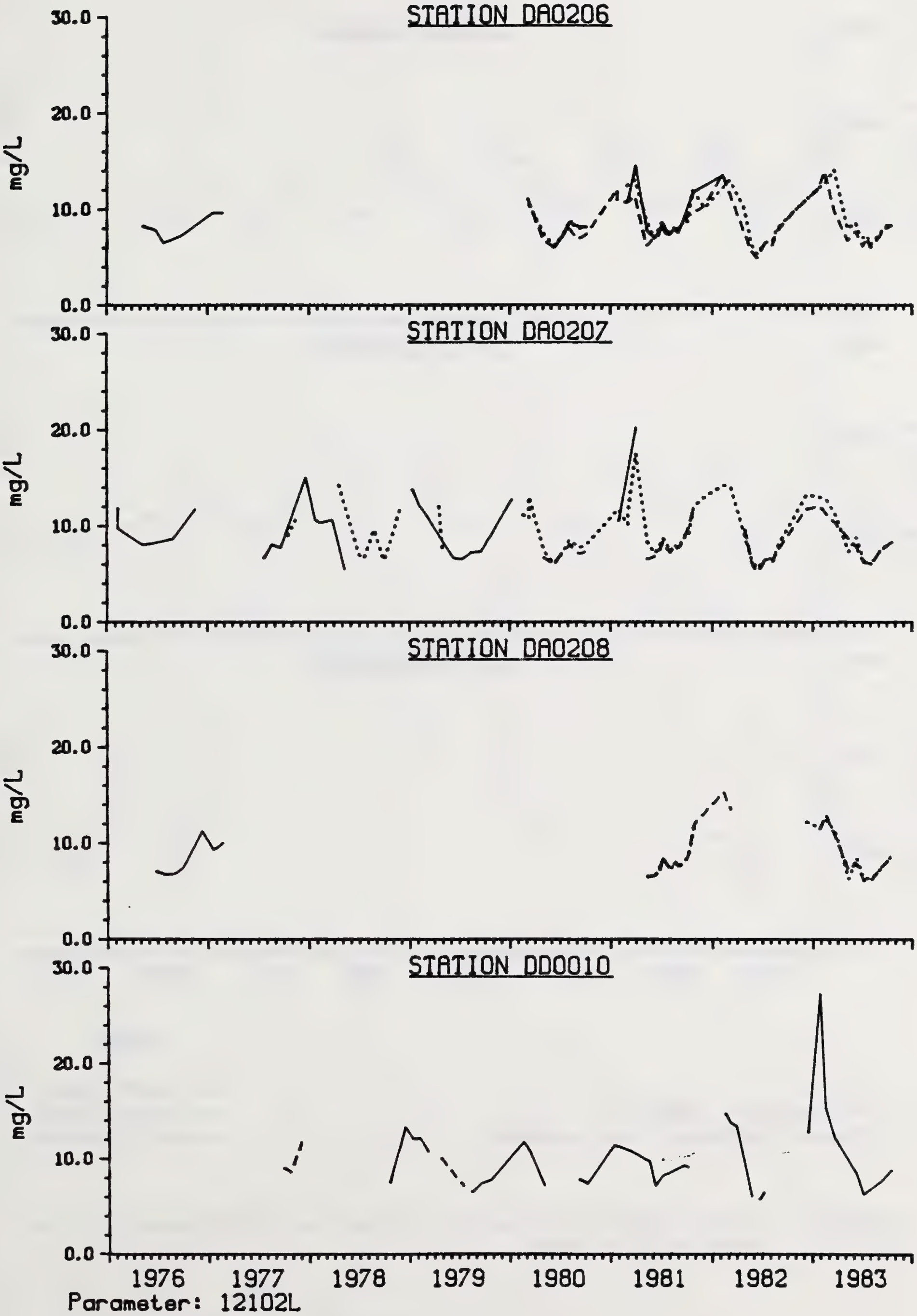

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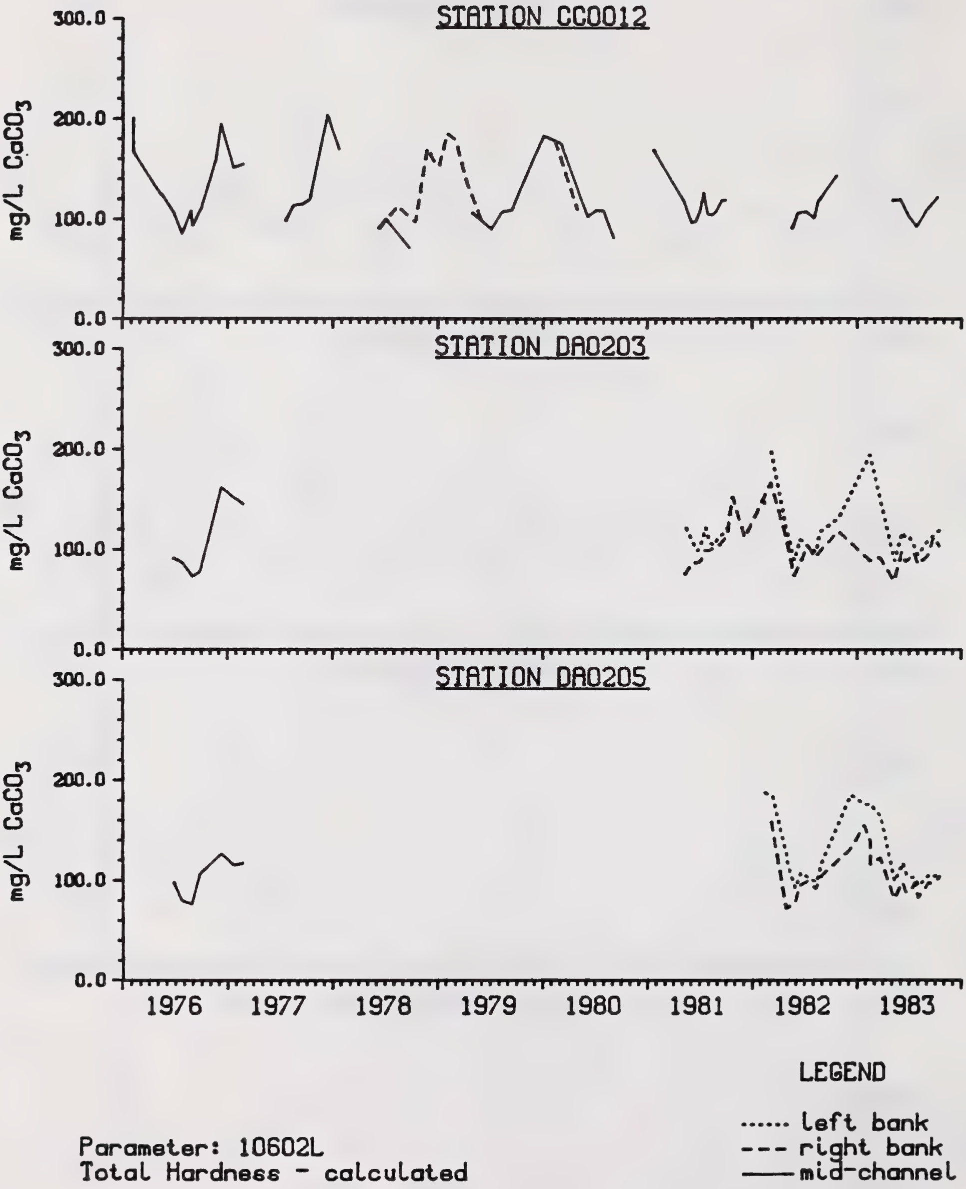

Figure 24. Total hardness at seven stations on the Athabasca River from 1976 to 1983.

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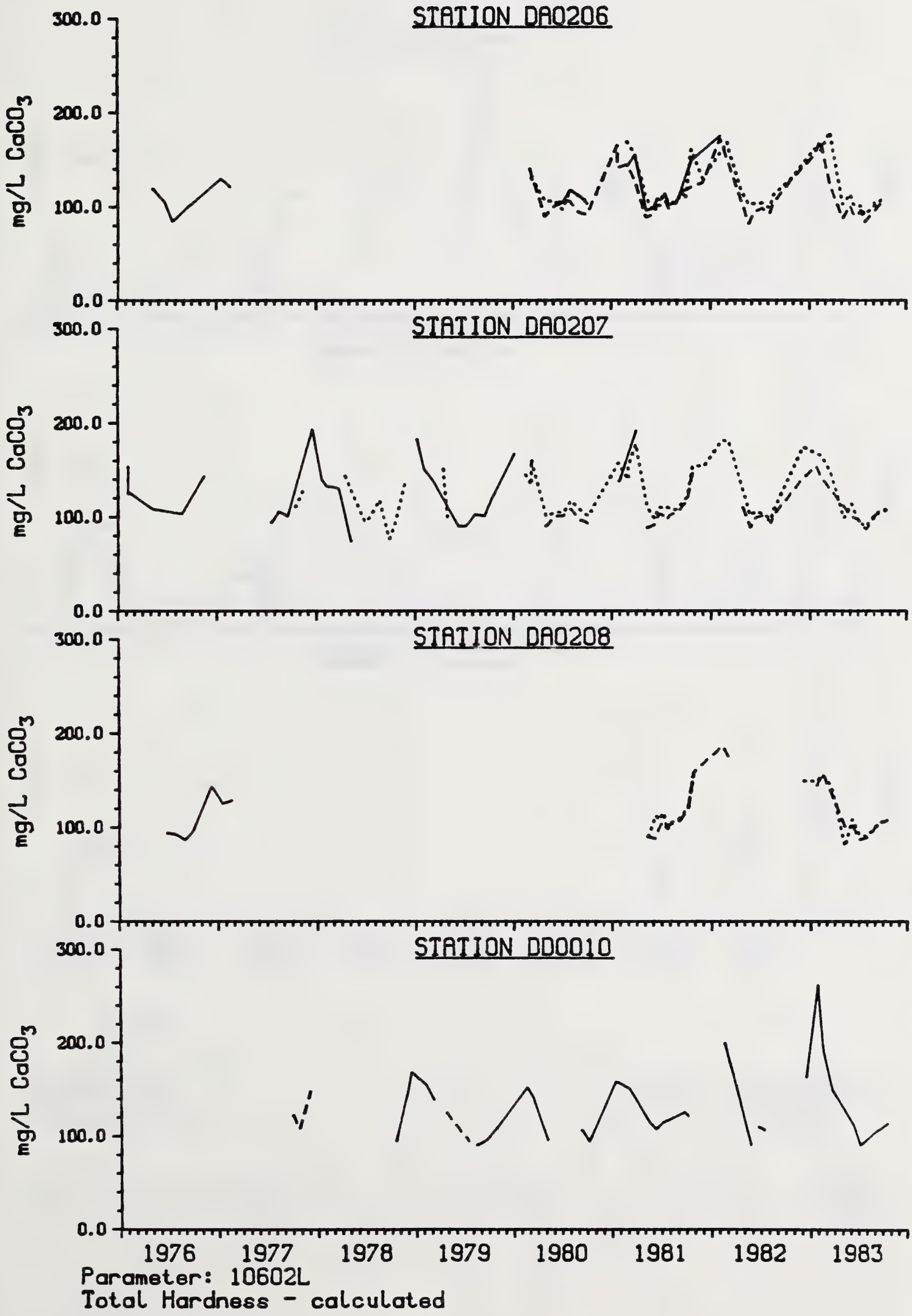

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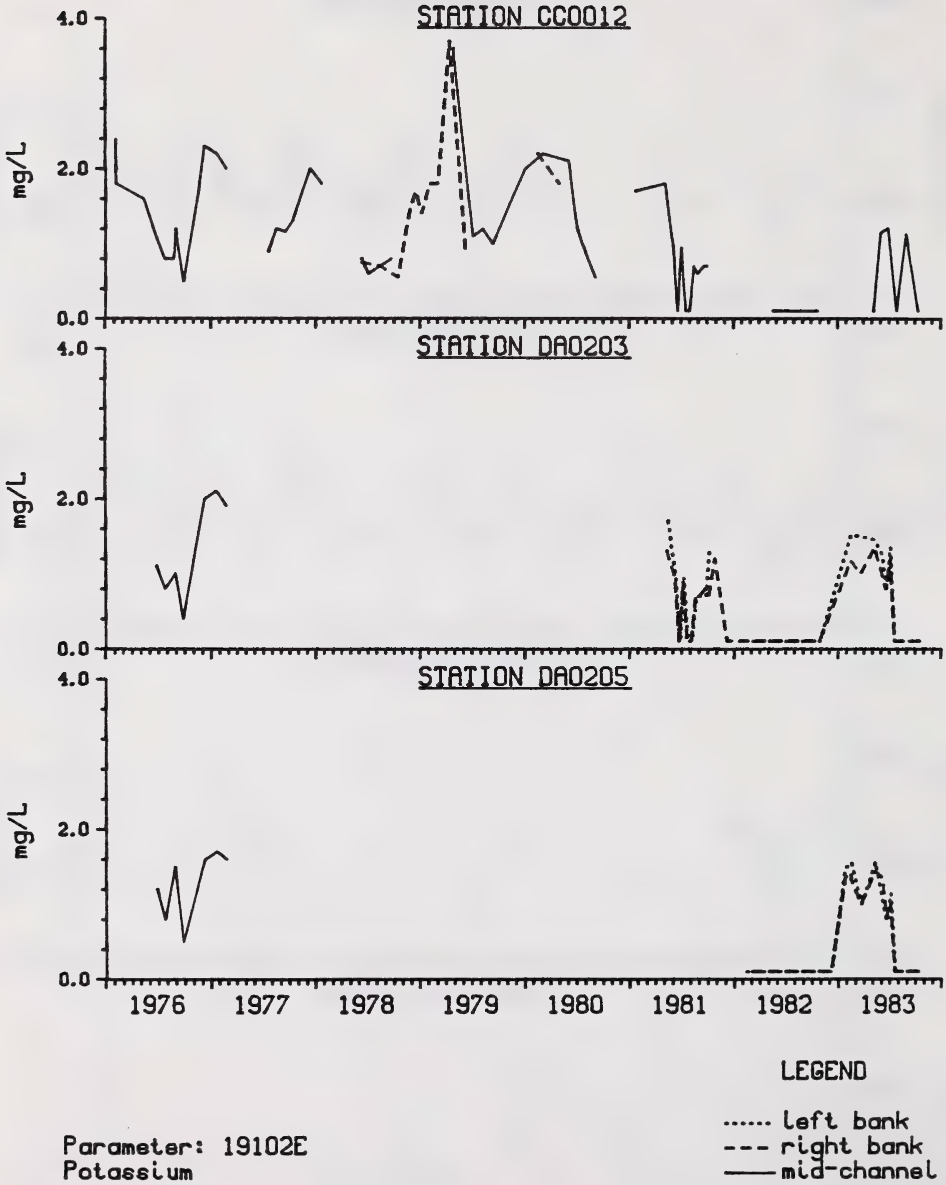

Figure 25. Potassium at seven stations on the Athabasca River from 1976 to 1983.

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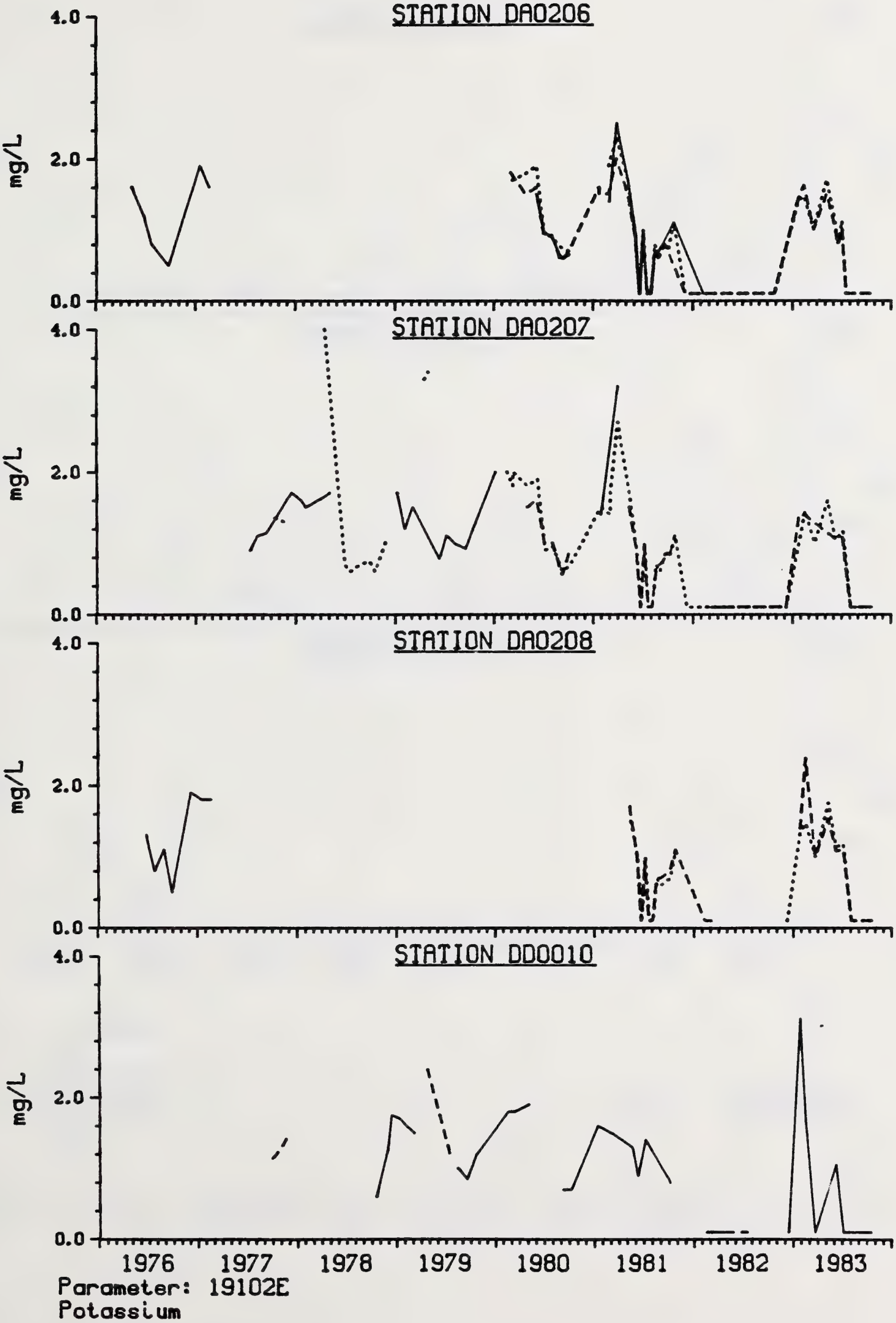

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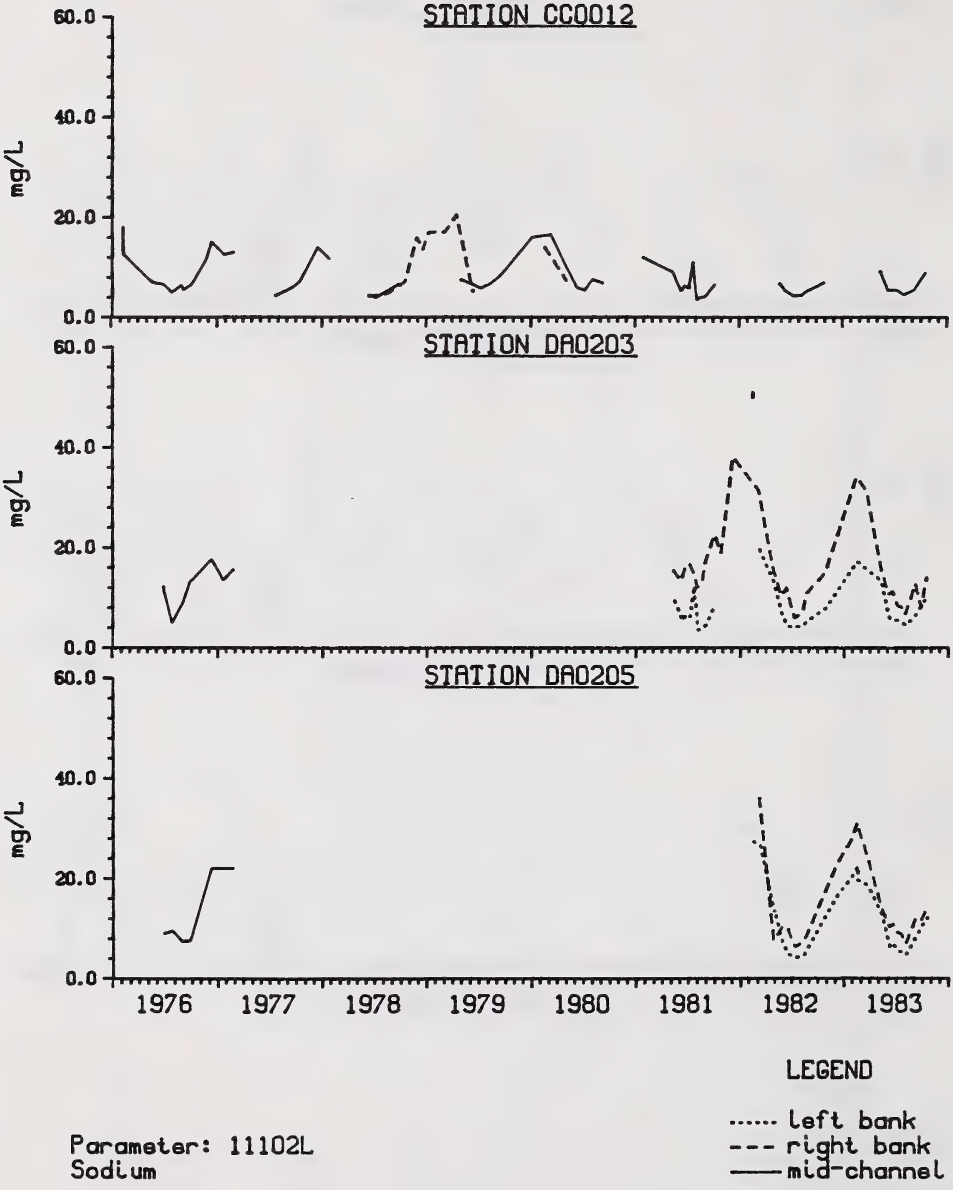

Figure 26. Sodium at seven stations on the Athabasca River from 1976 to 1983.

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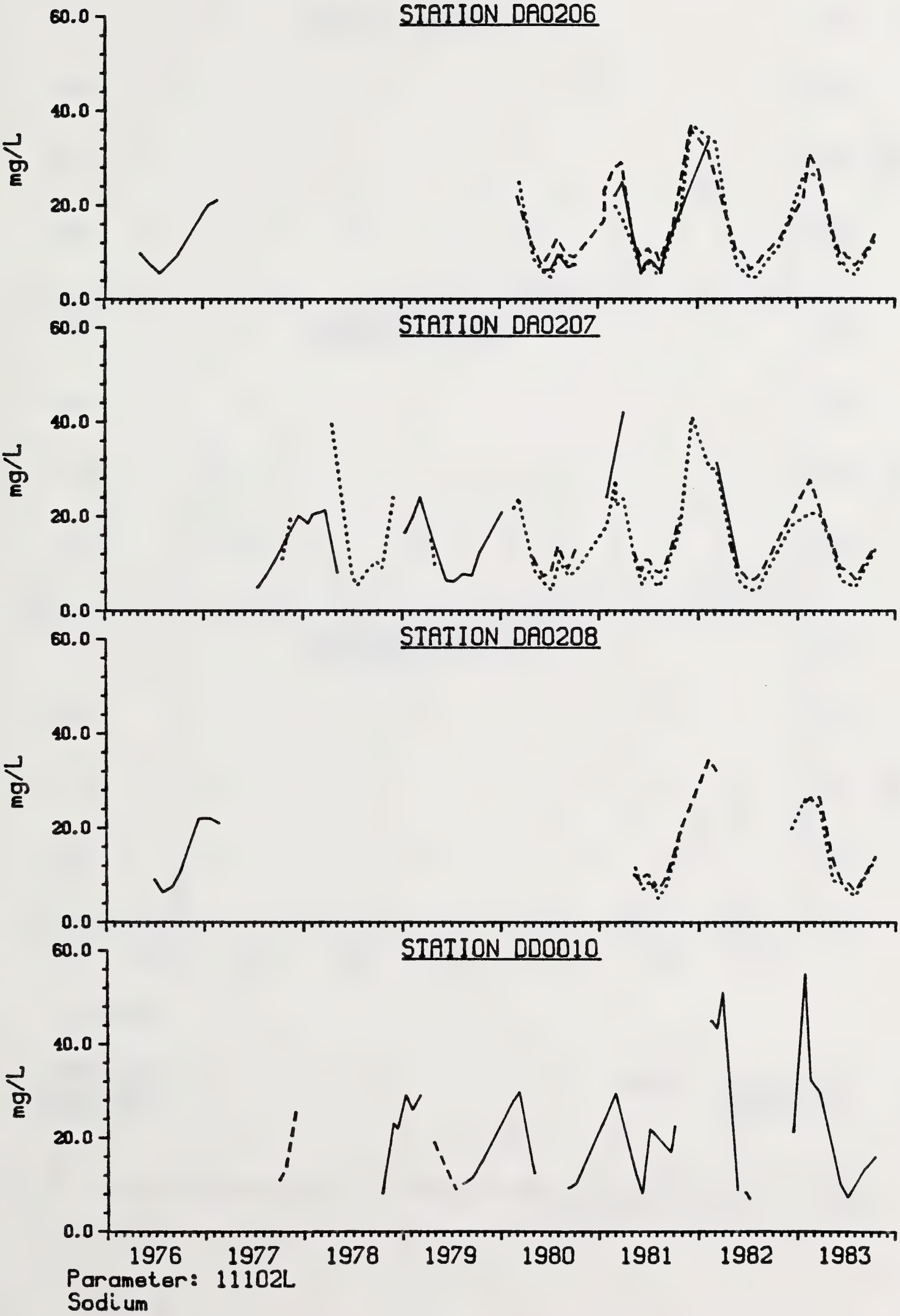

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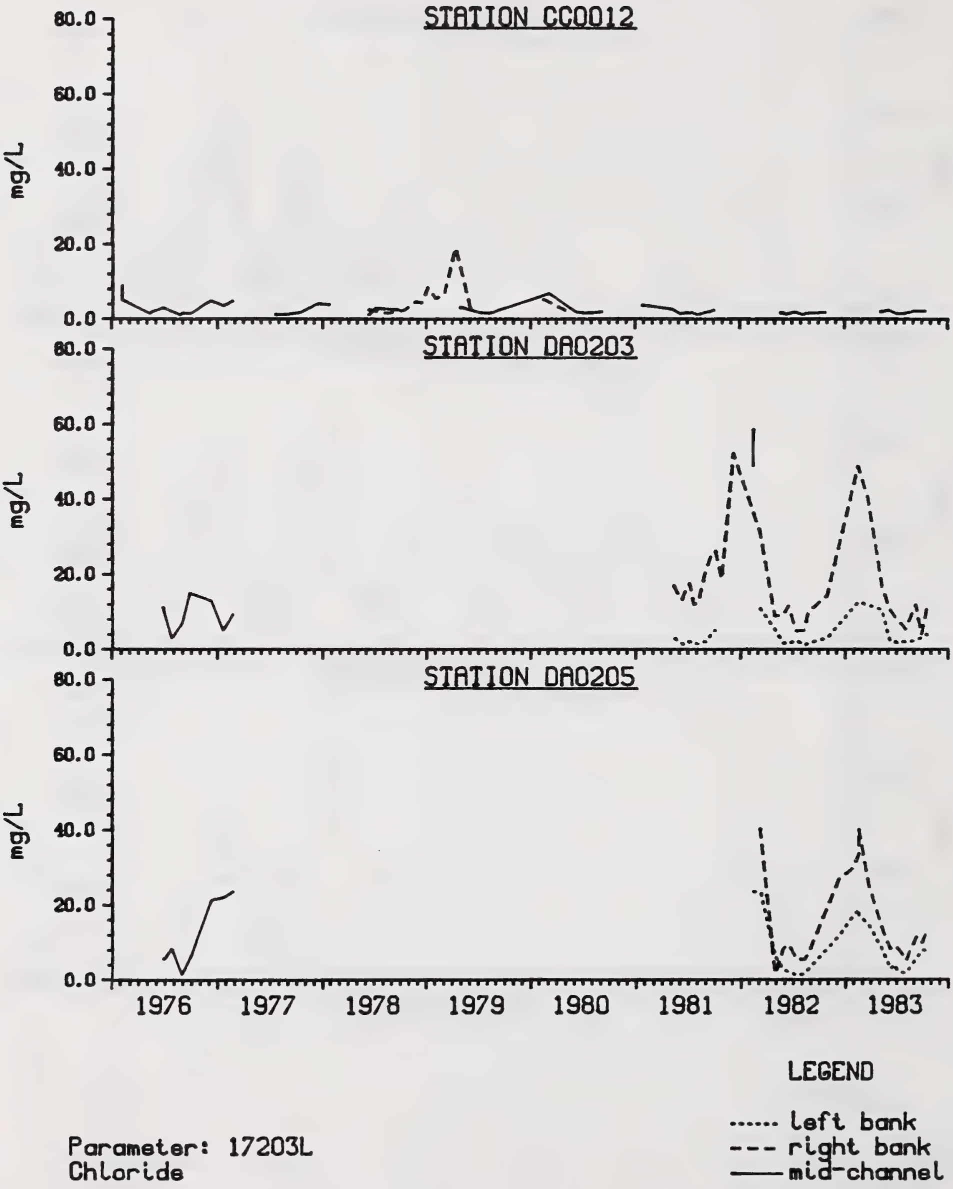

Figure 27. Chloride at seven stations on the Athabasca River from 1976 to 1983.

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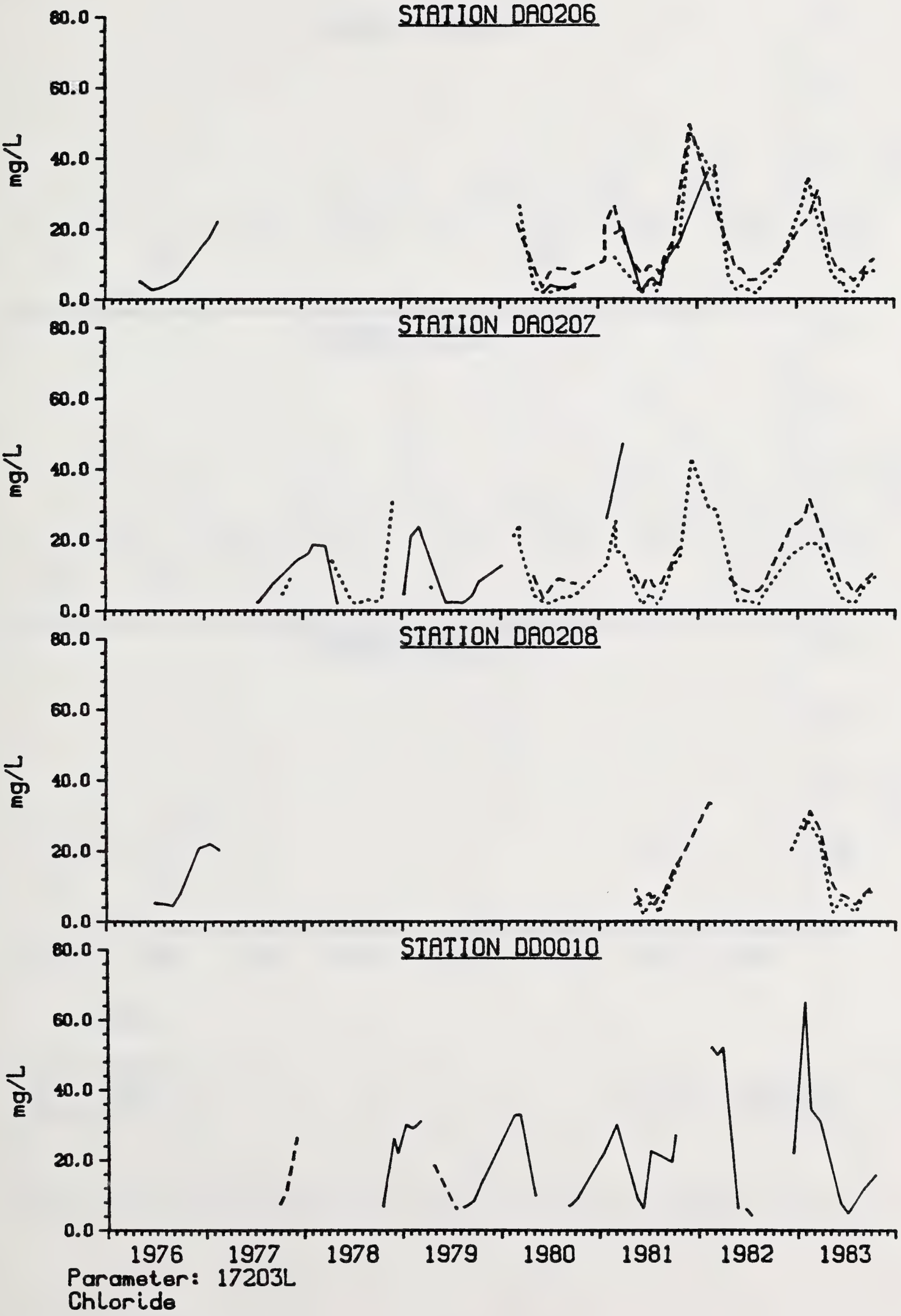

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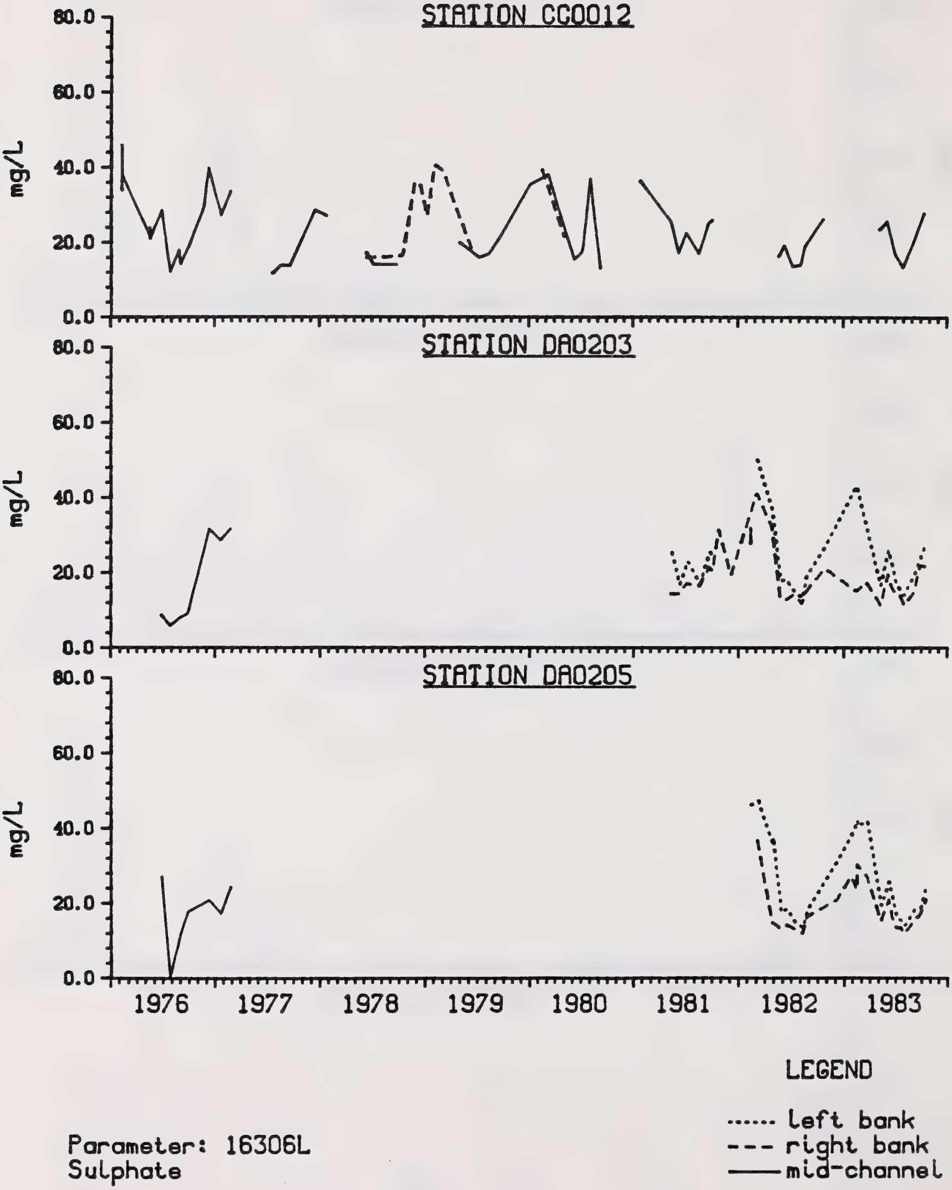
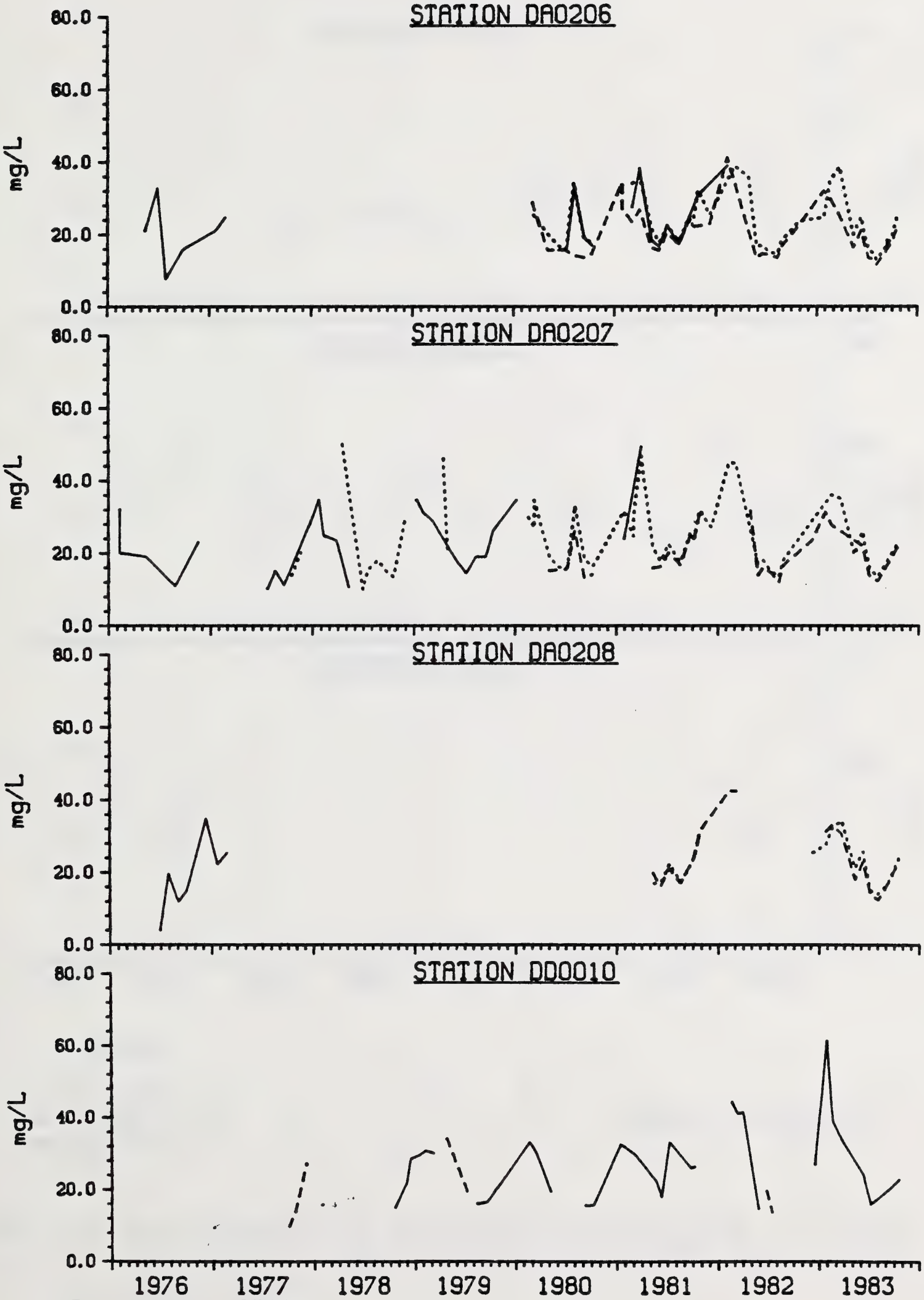


Figure 28. Sulphate at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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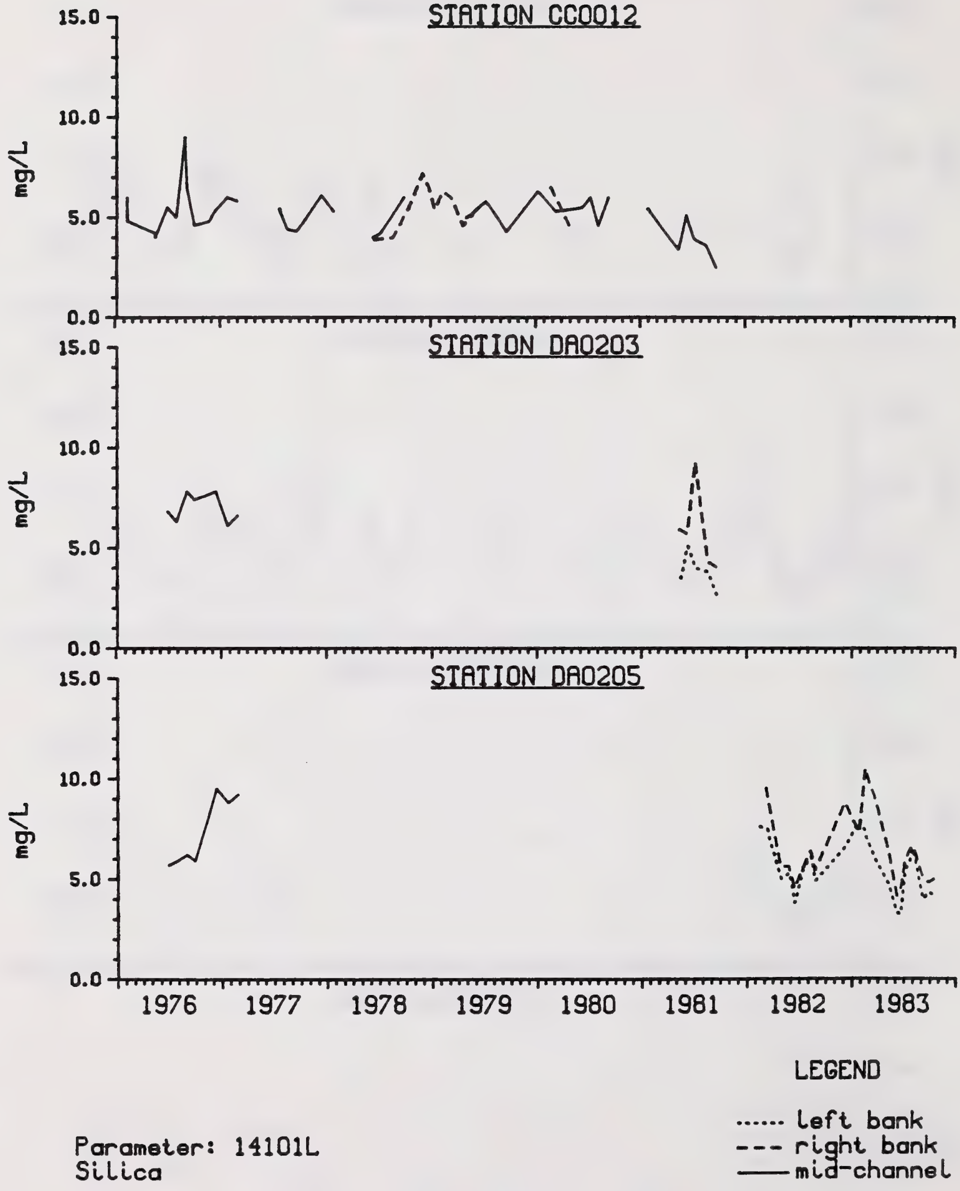
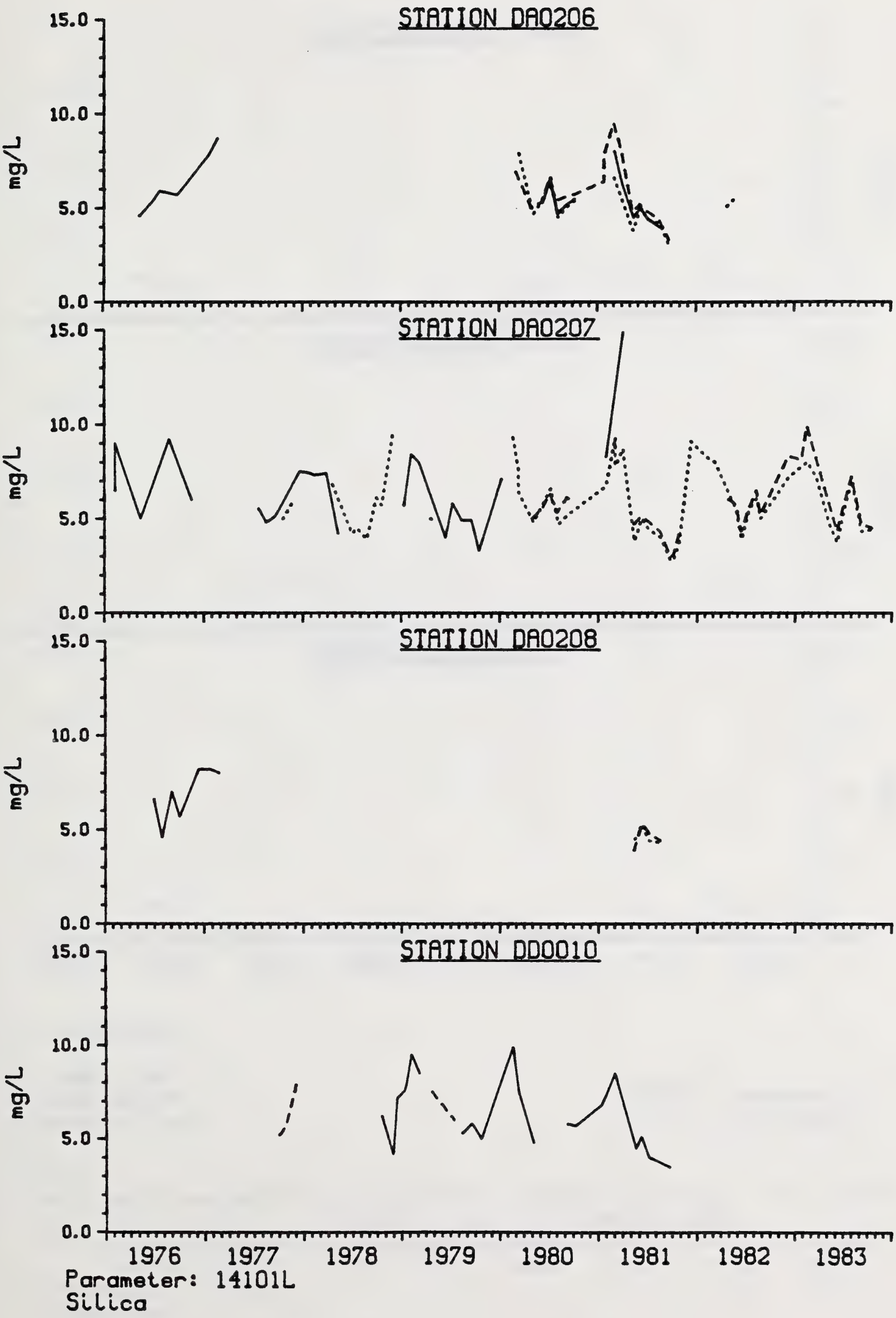


Figure 29. Silica at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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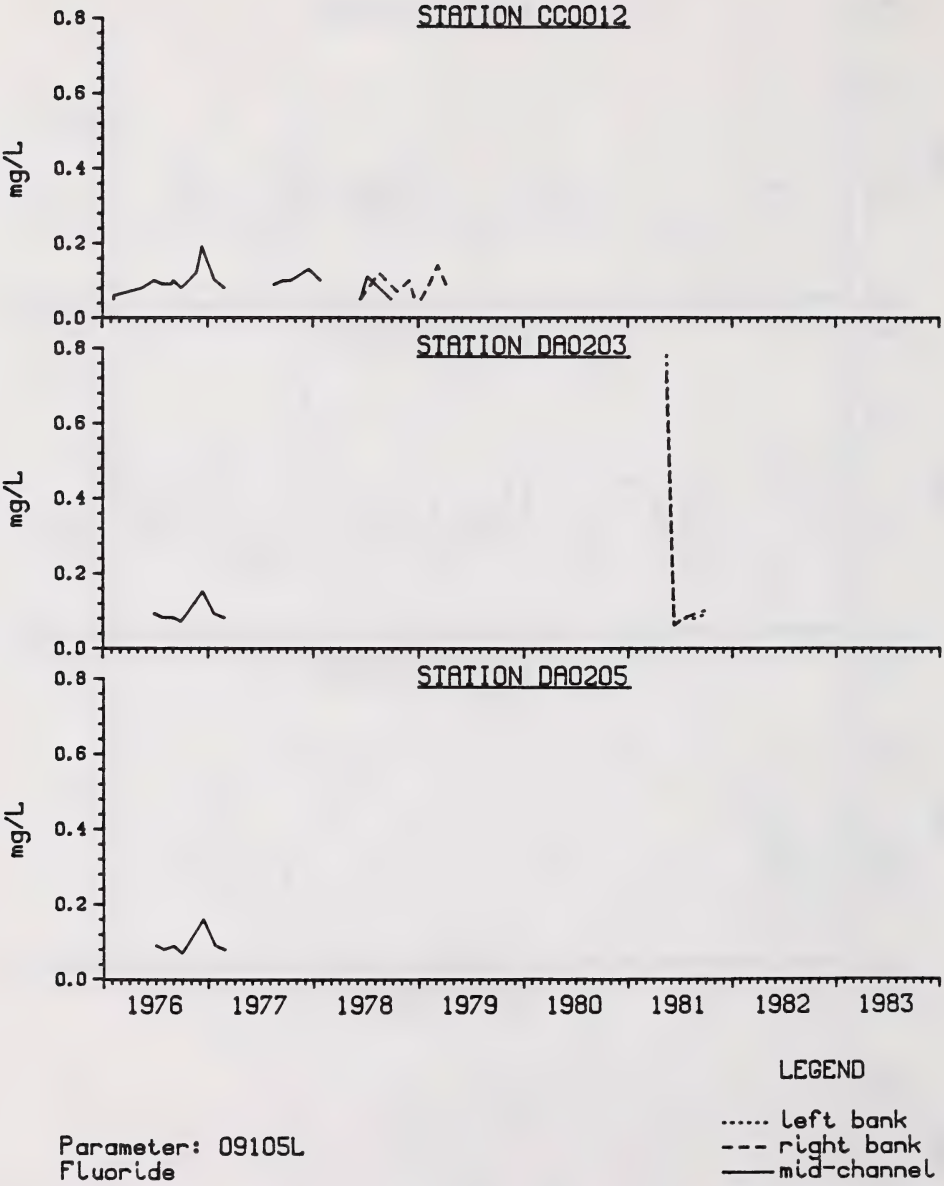
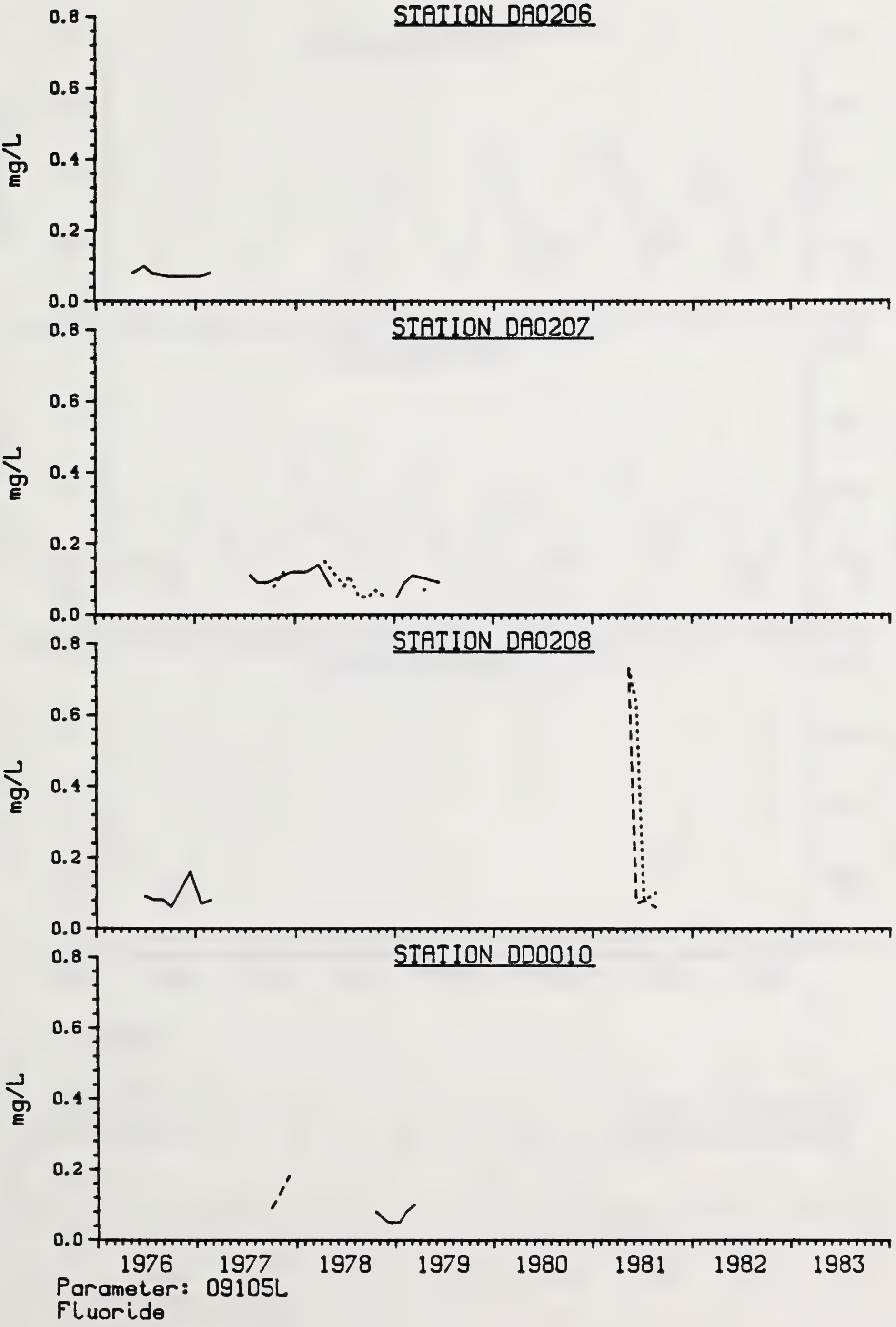


Figure 30. Fluoride at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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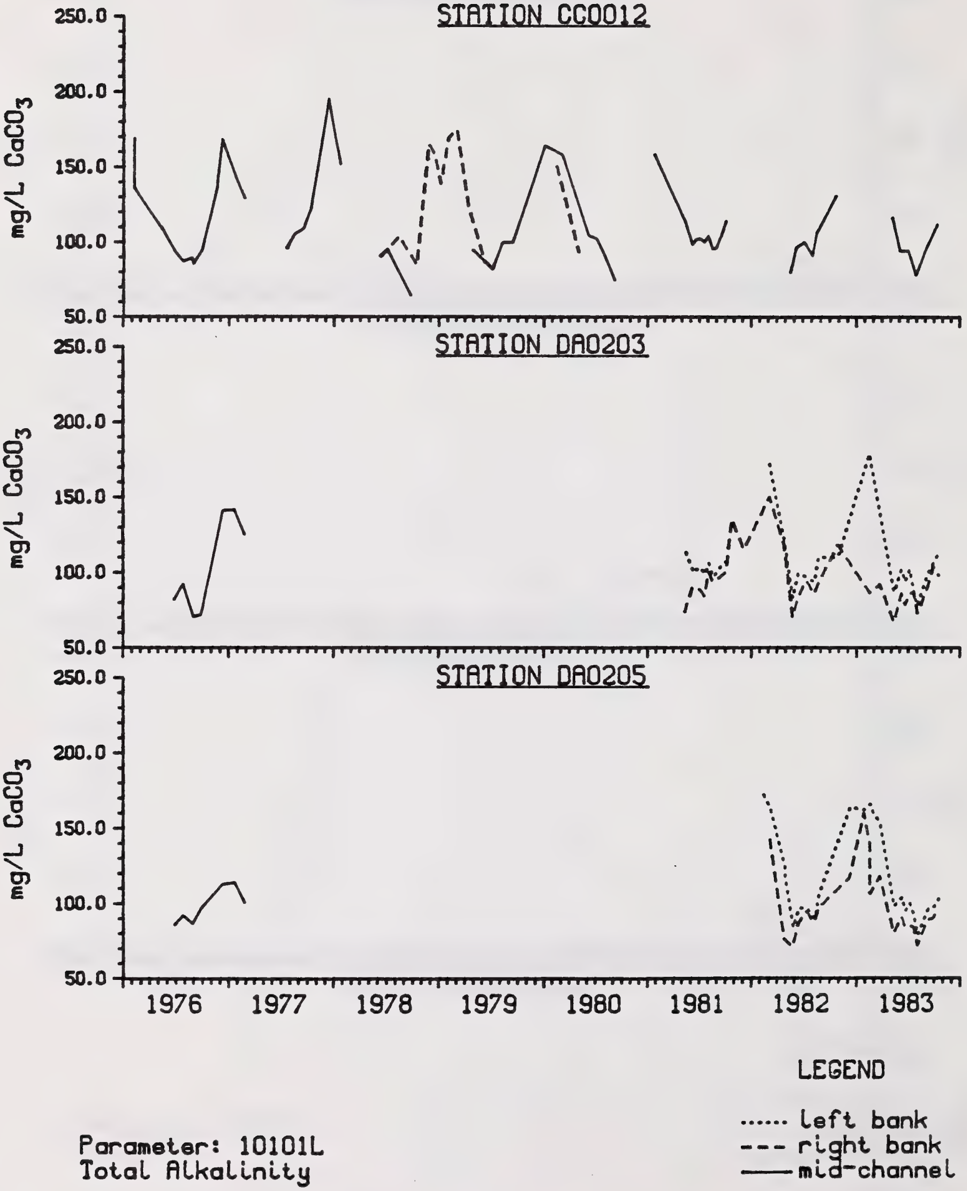
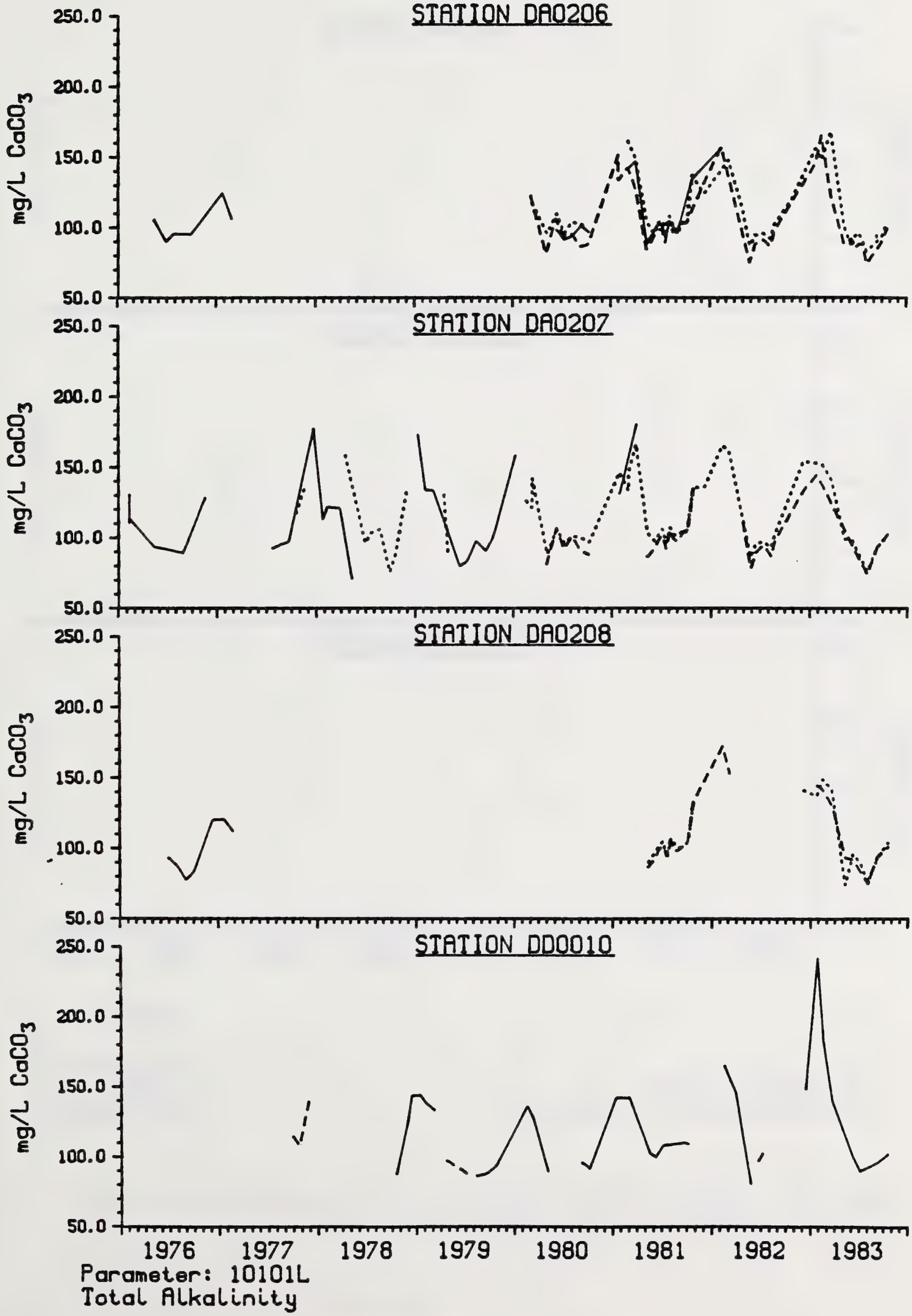


Figure 31. Total alkalinity at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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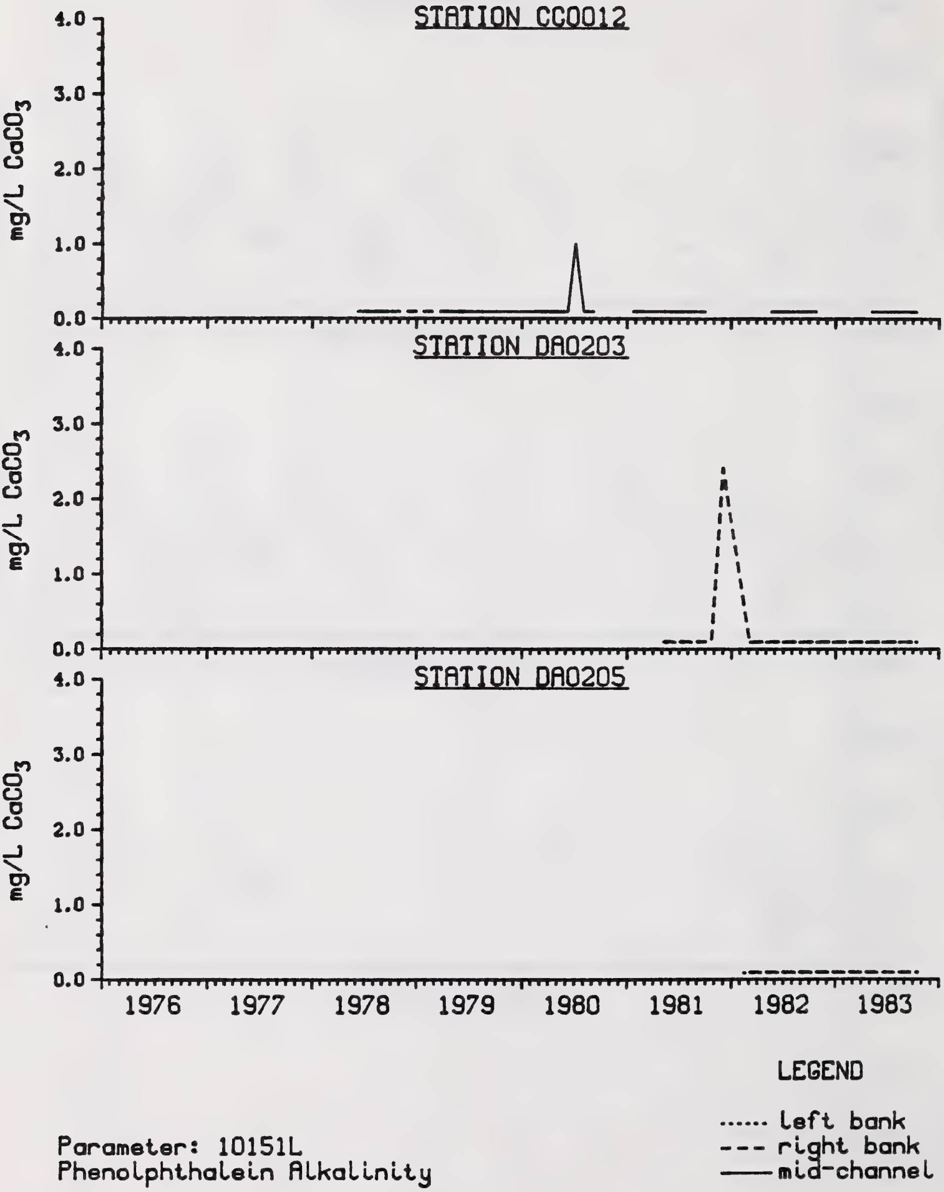
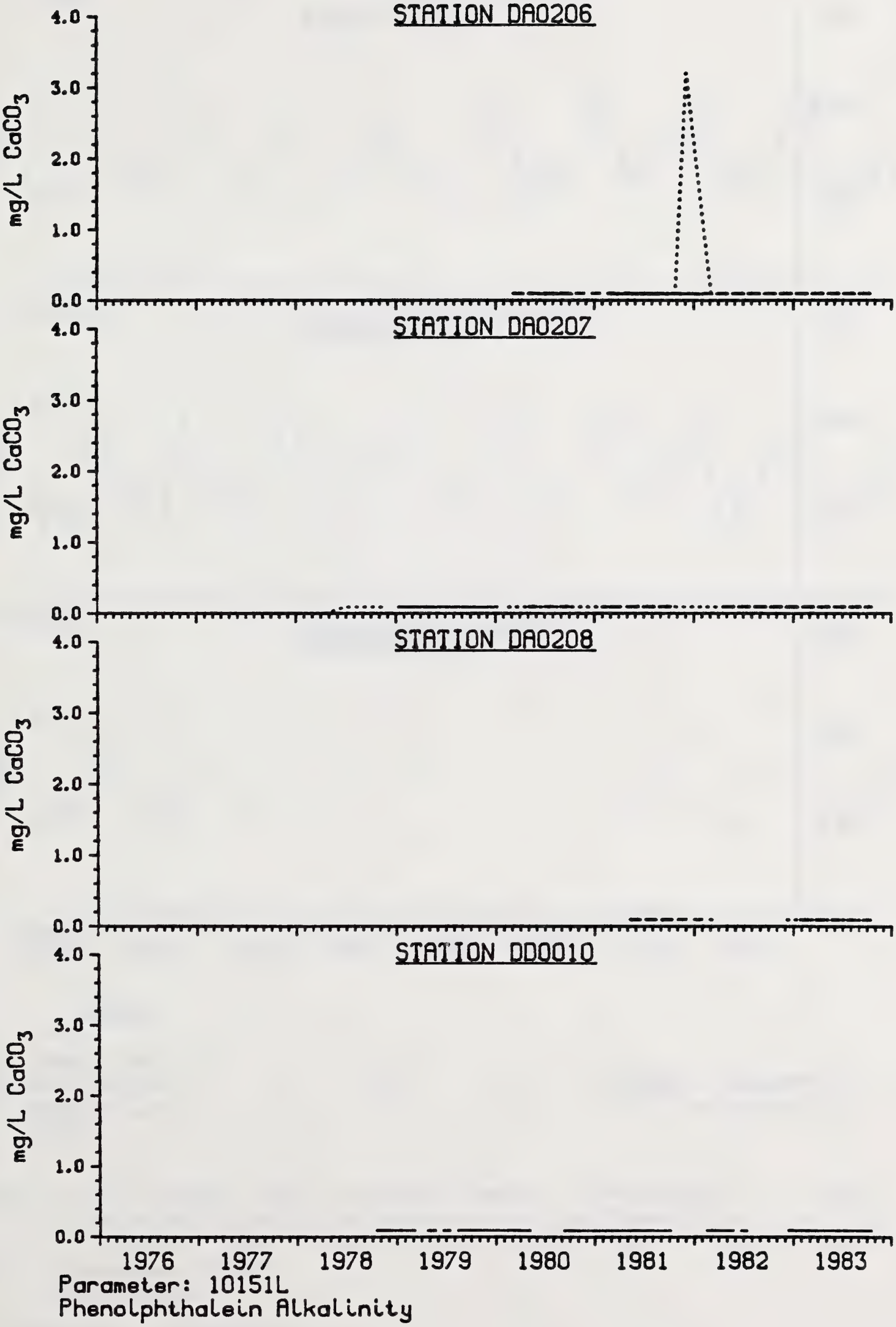


Figure 32. Phenolphthalein alkalinity at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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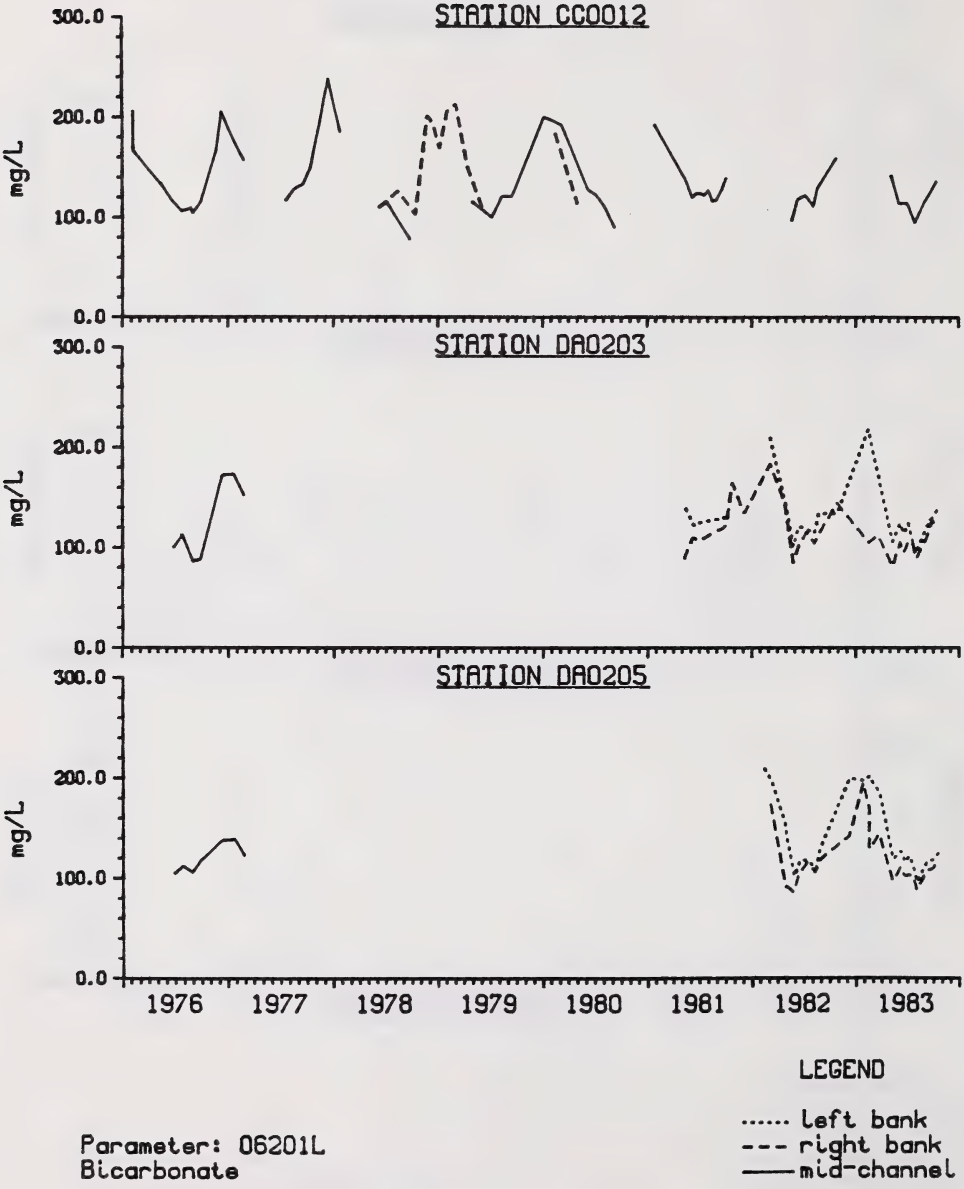
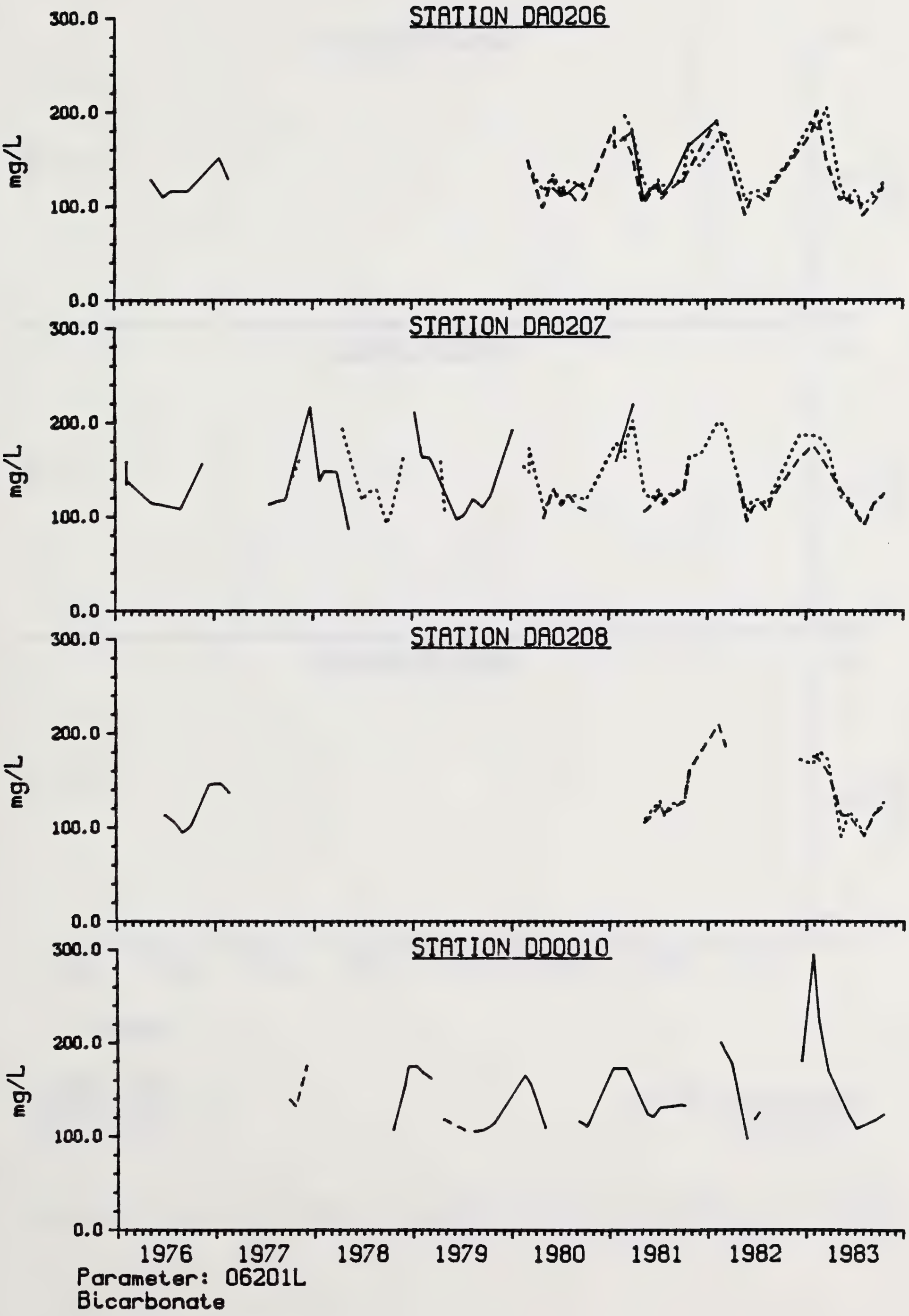


Figure 33. Bicarbonate at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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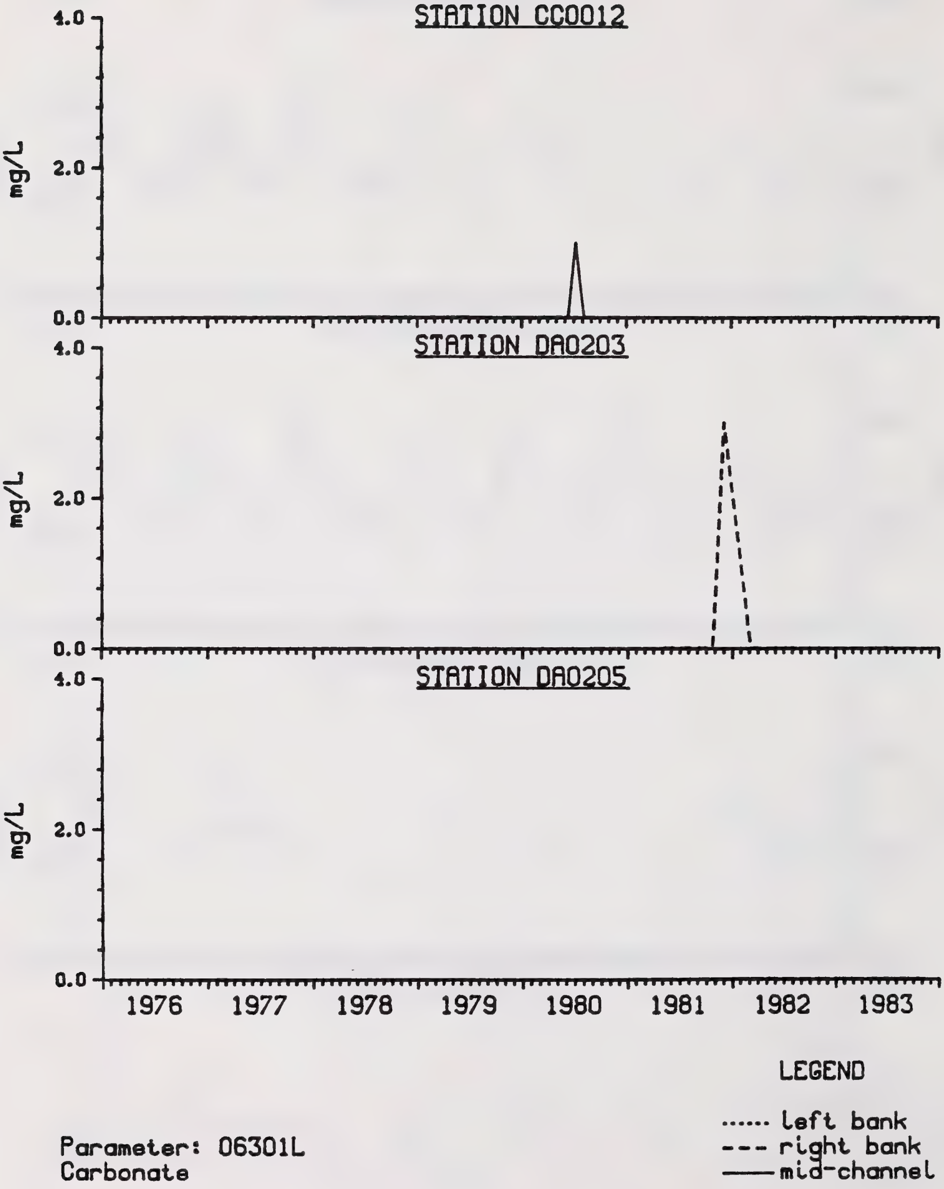

Figure 34. Carbonate at seven stations on the Athabasca River from 1976 to 1983.

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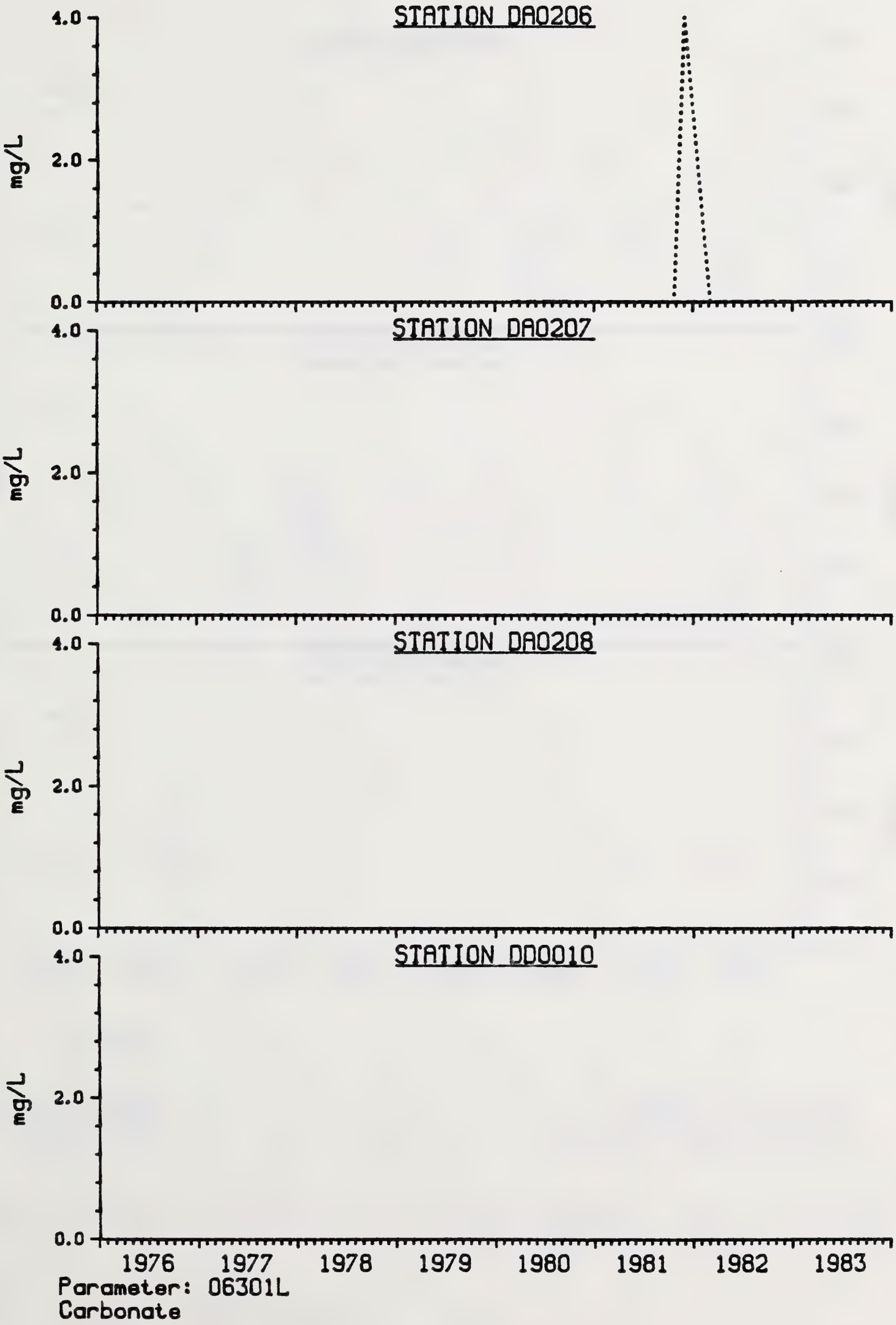

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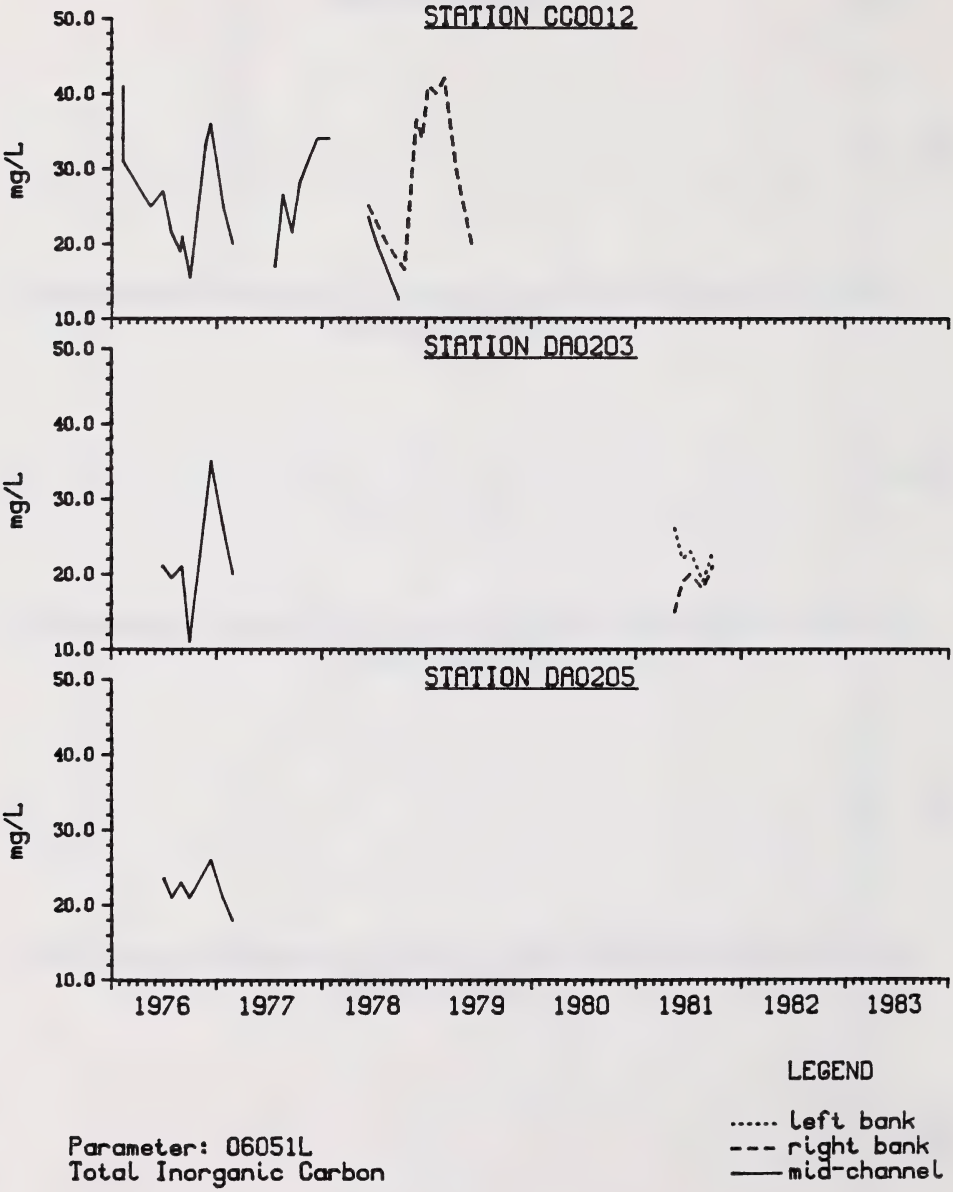
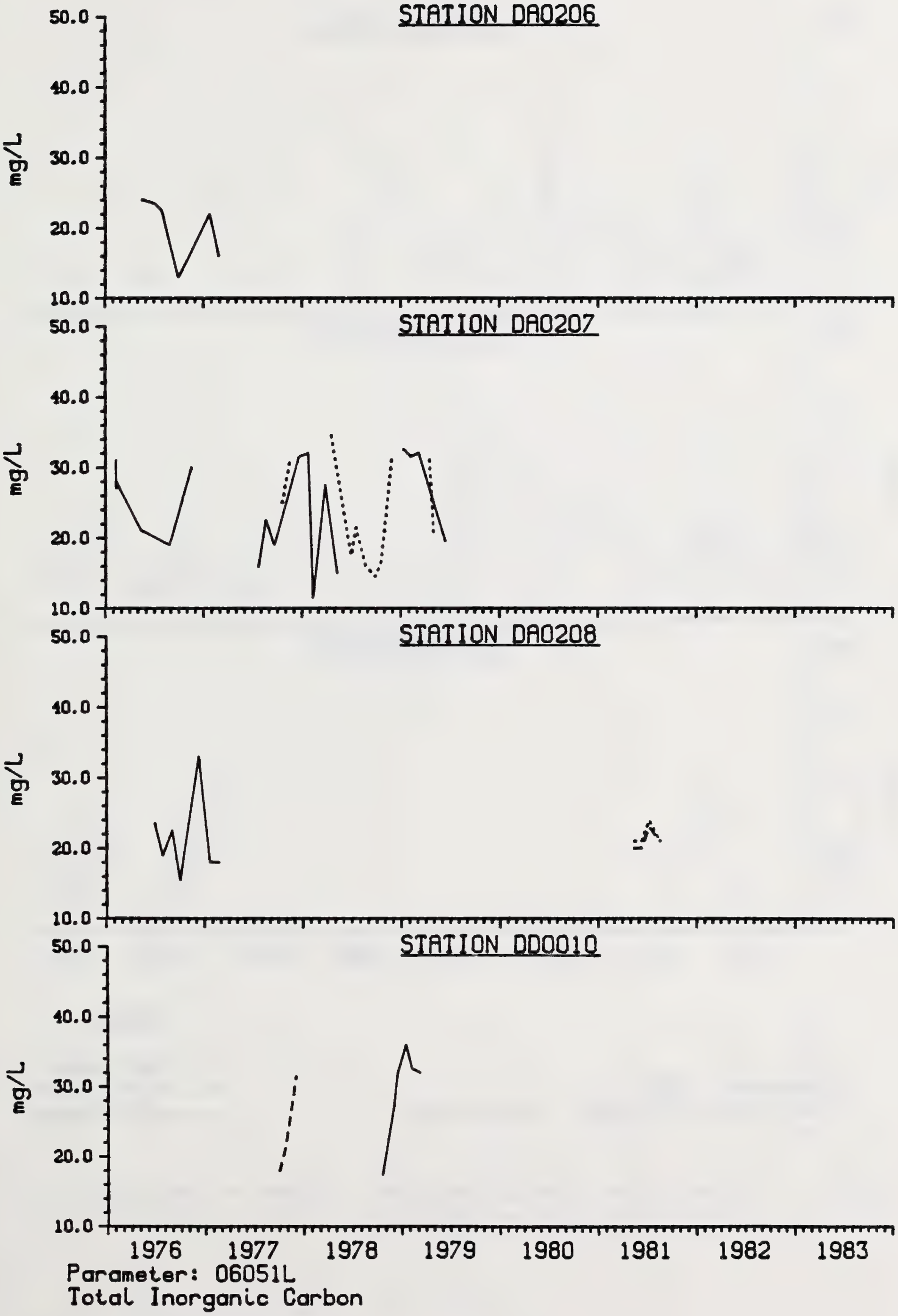


Figure 35. Total inorganic carbon at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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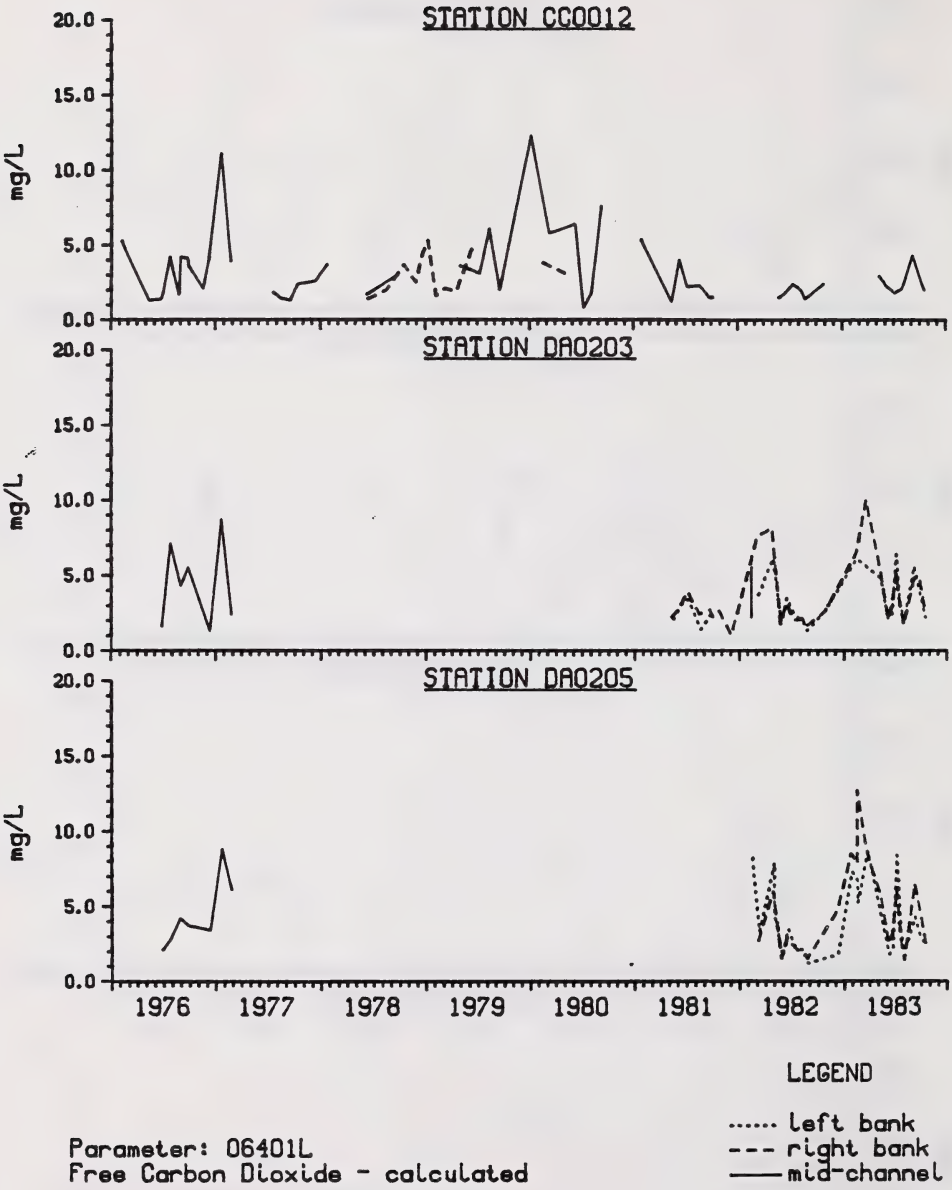
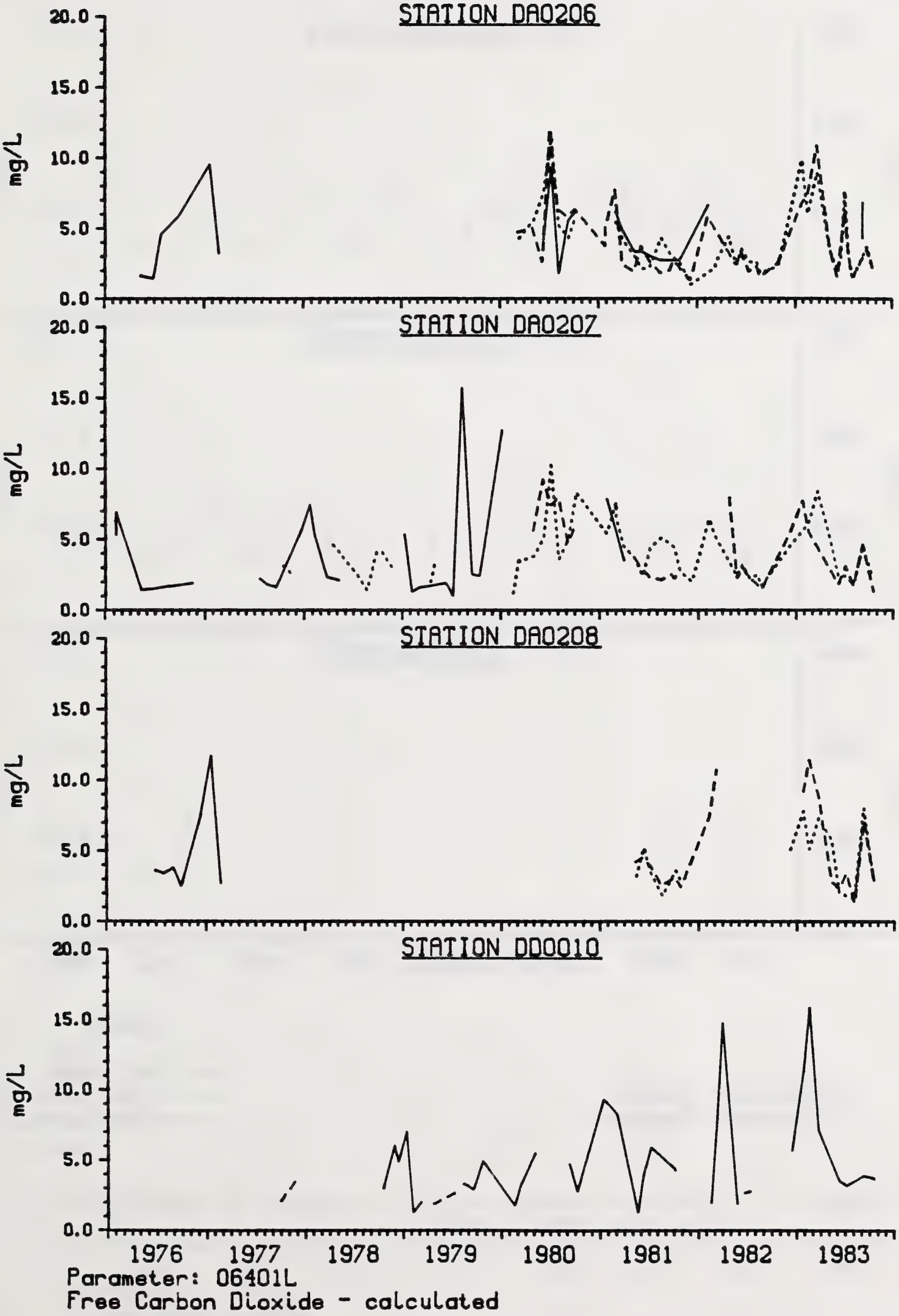


Figure 36. Free carbon dioxide at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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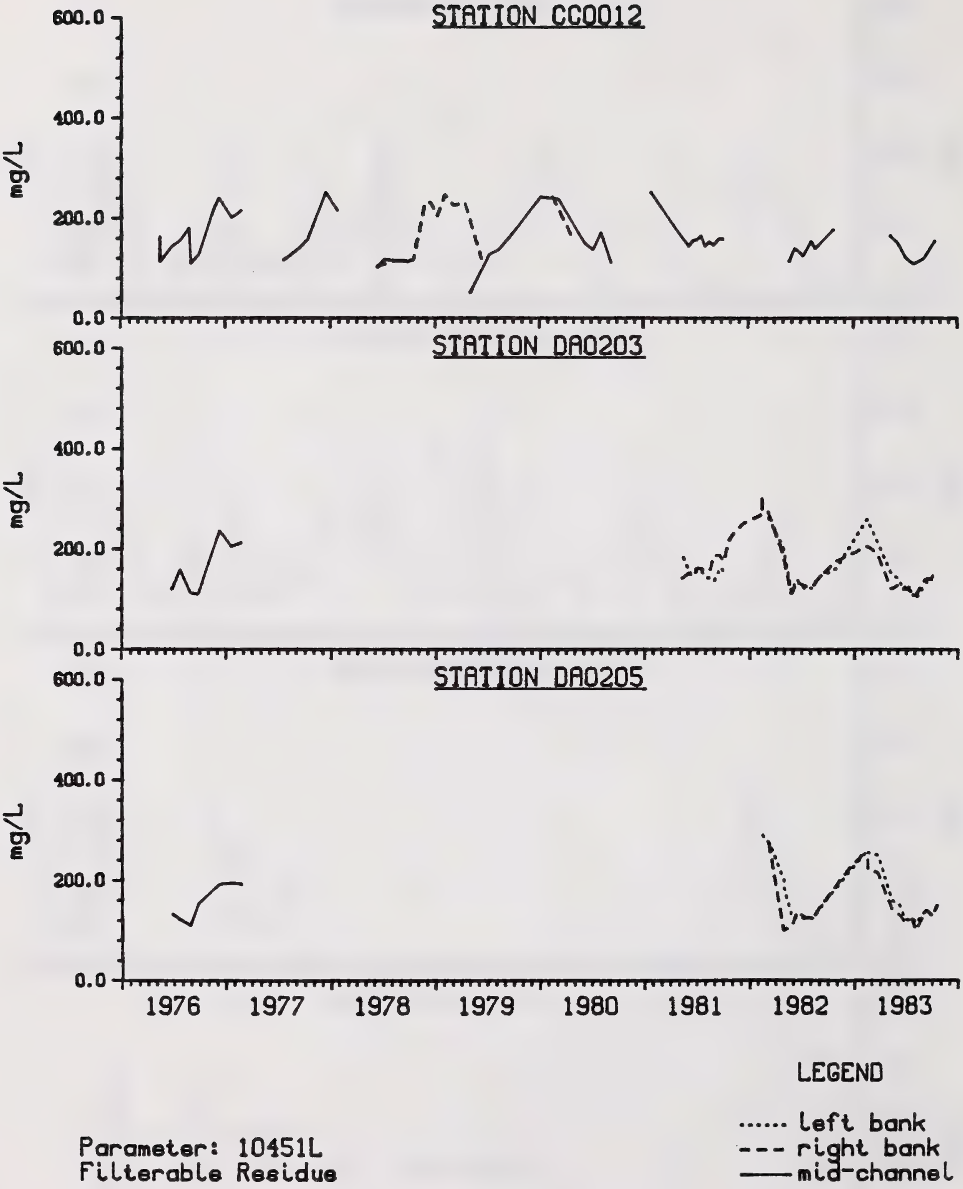
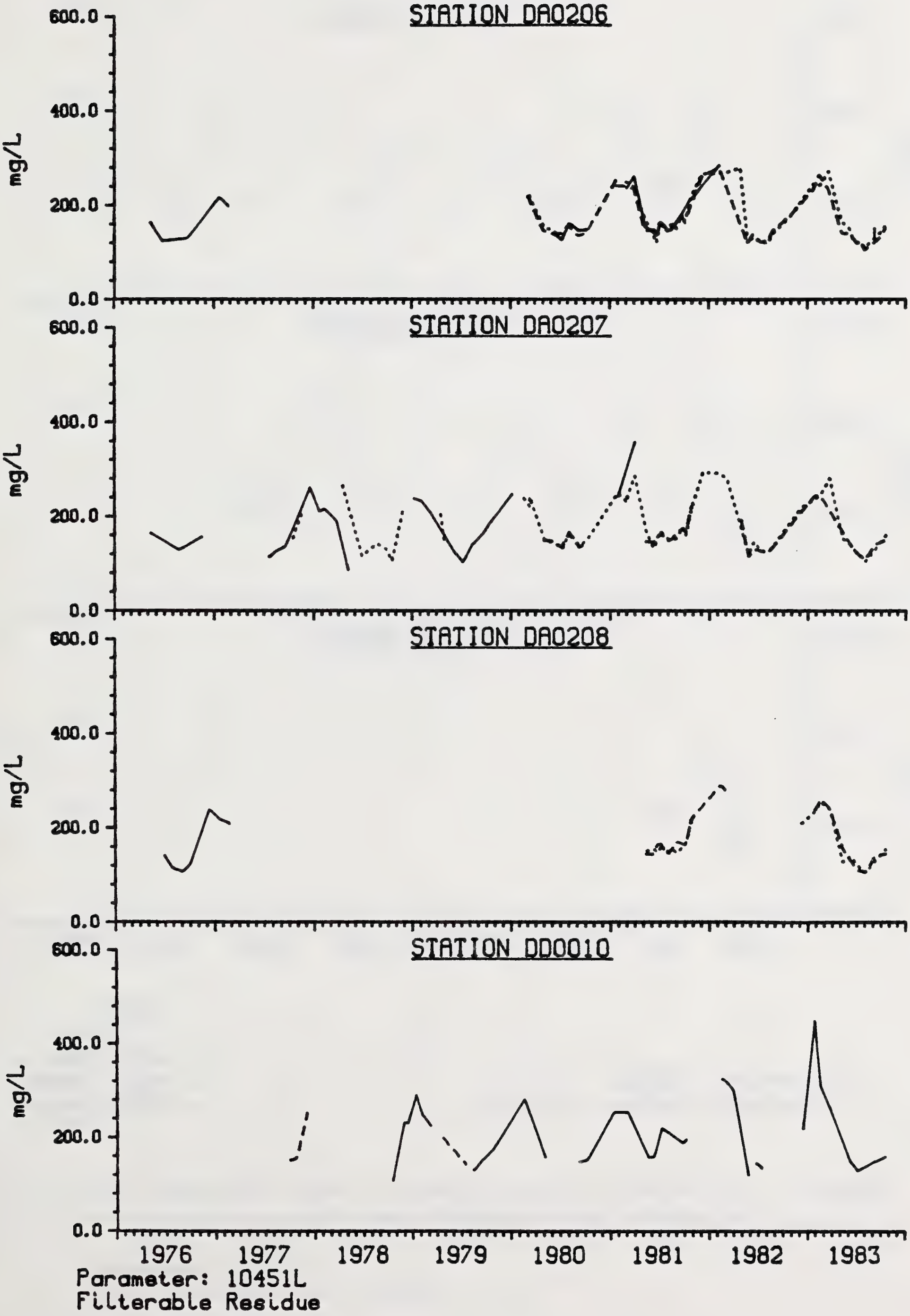


Figure 37. Filterable residue at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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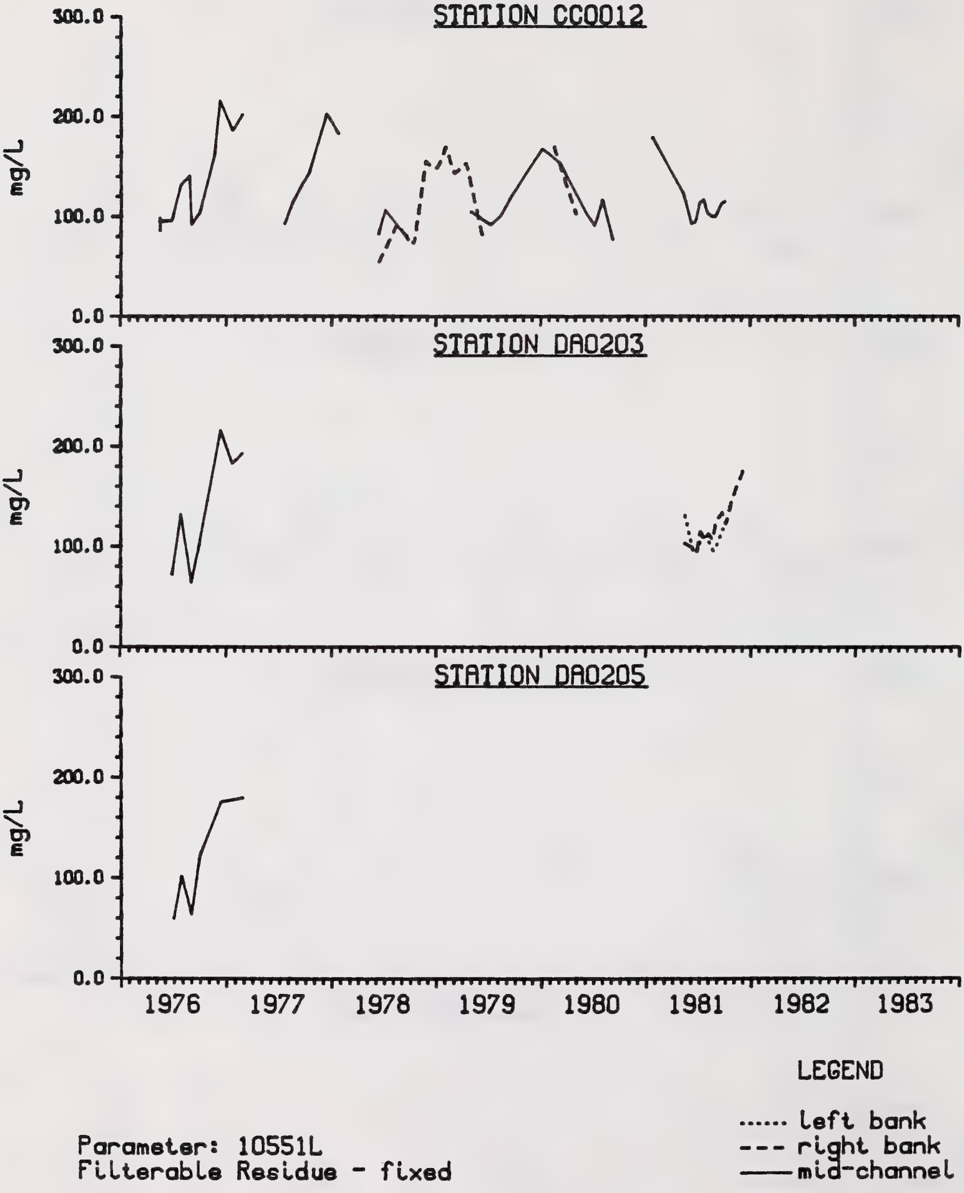
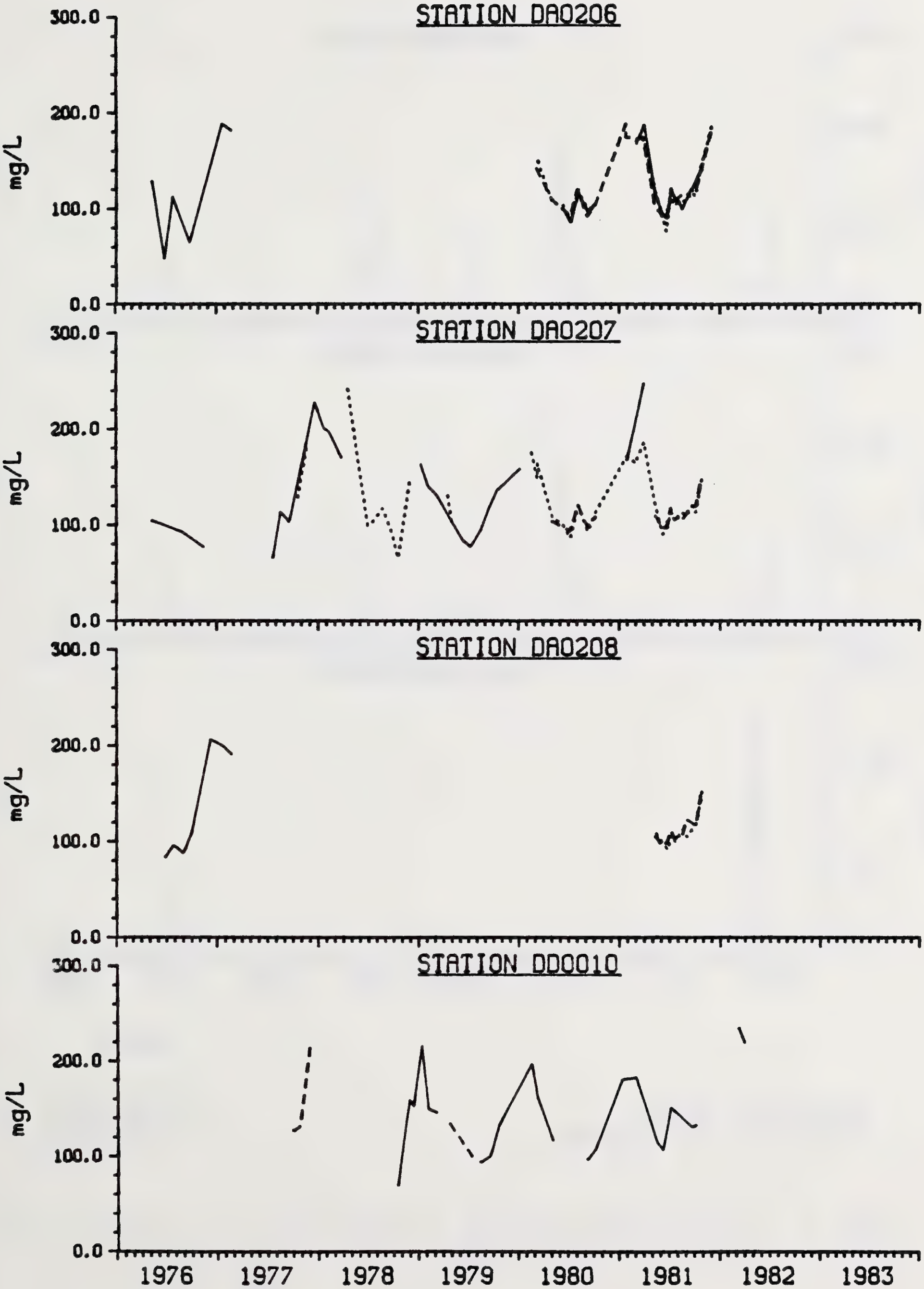


Figure 38. Filterable residue (fixed) at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



Parameter: 10551L
Filterable Residue - fixed

Figure 38. Concluded.

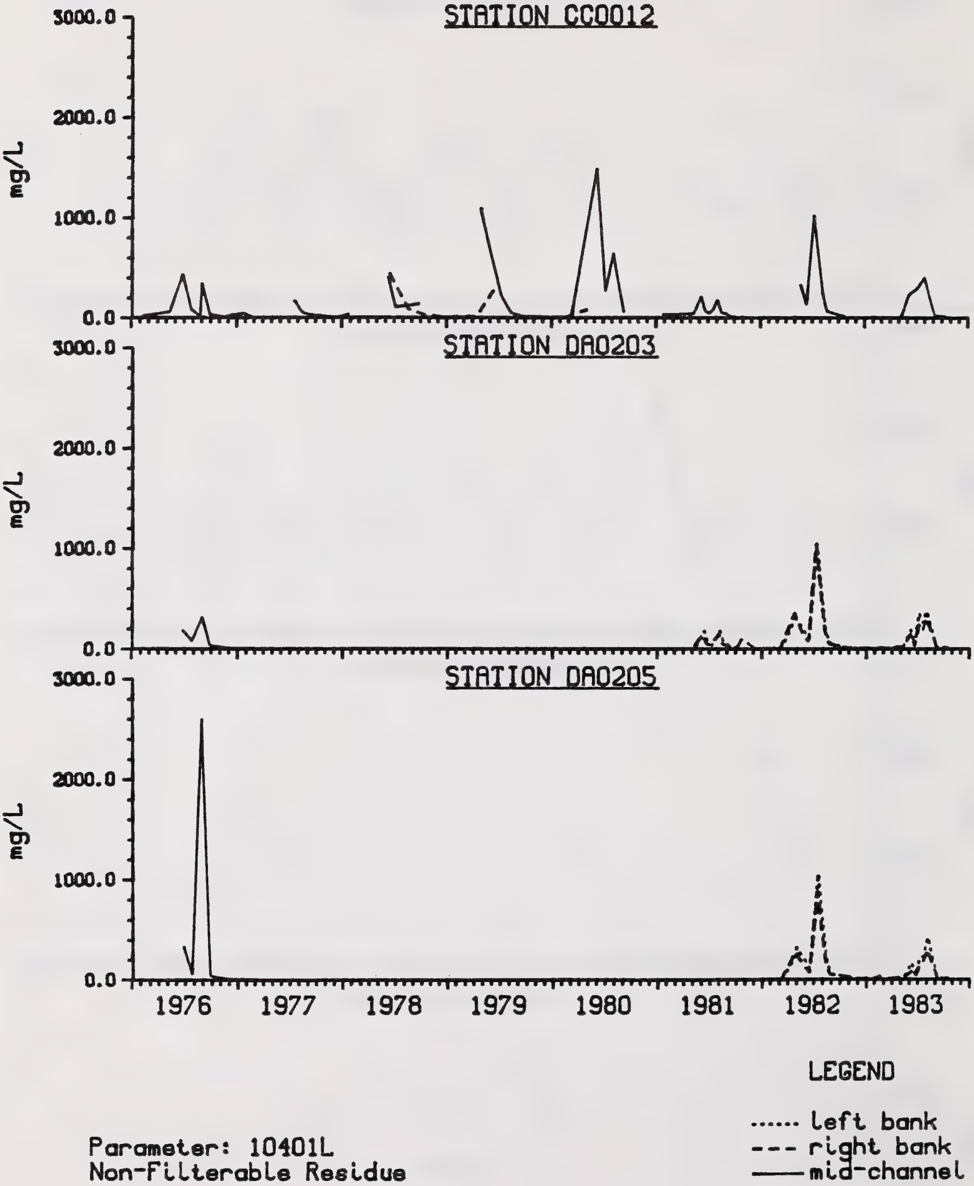


Figure 39. Non-filterable residue at seven stations on the Athabasca River from 1976 to 1983.

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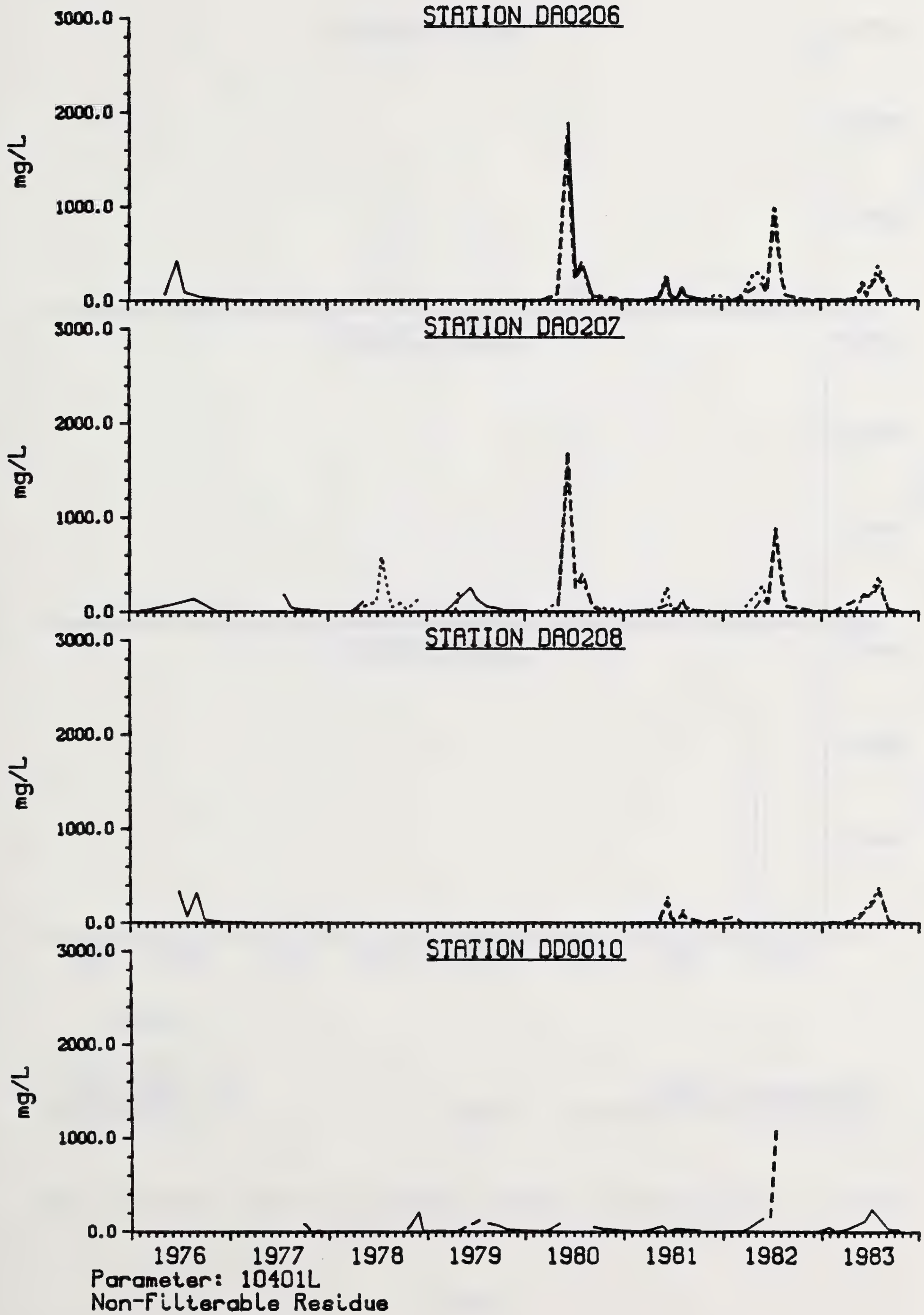

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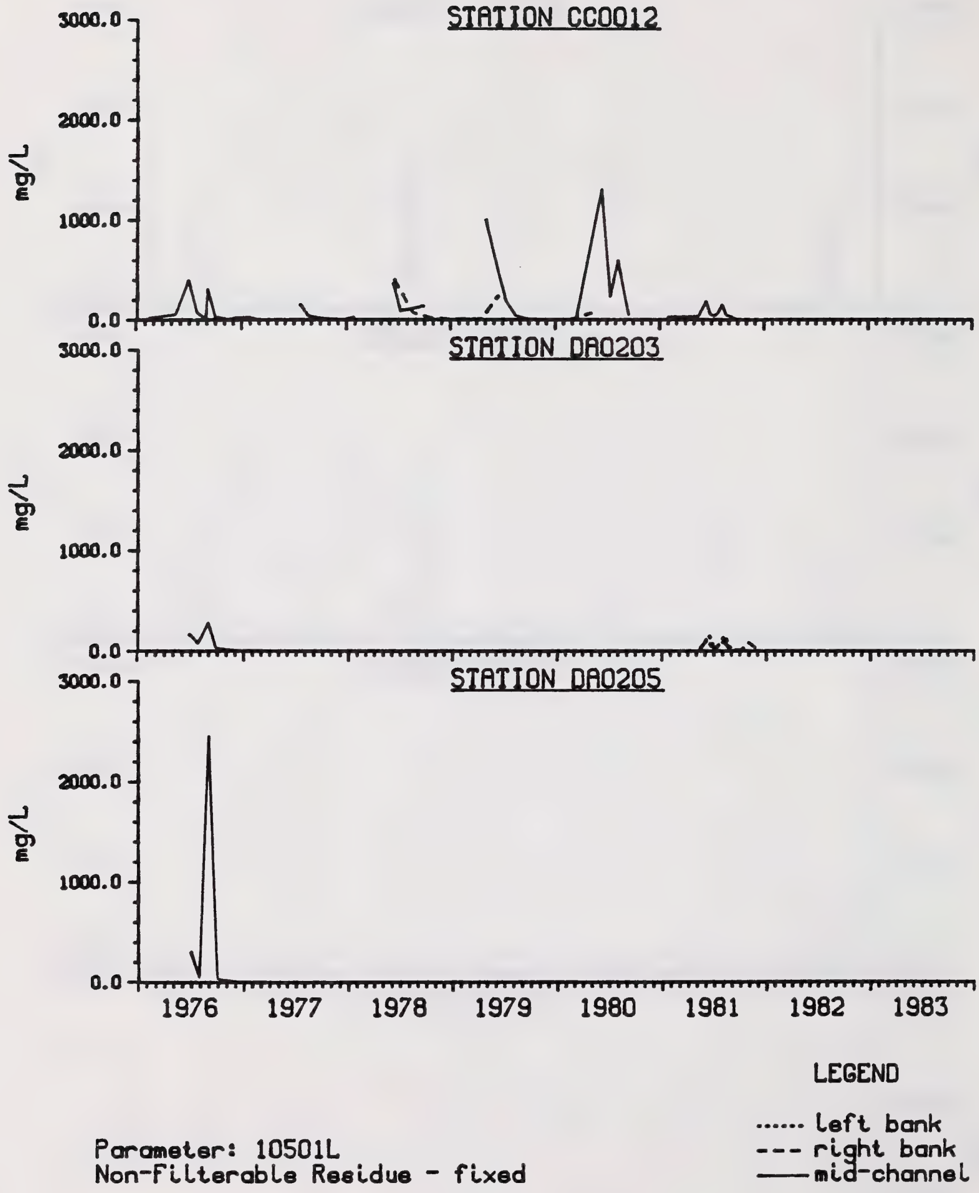
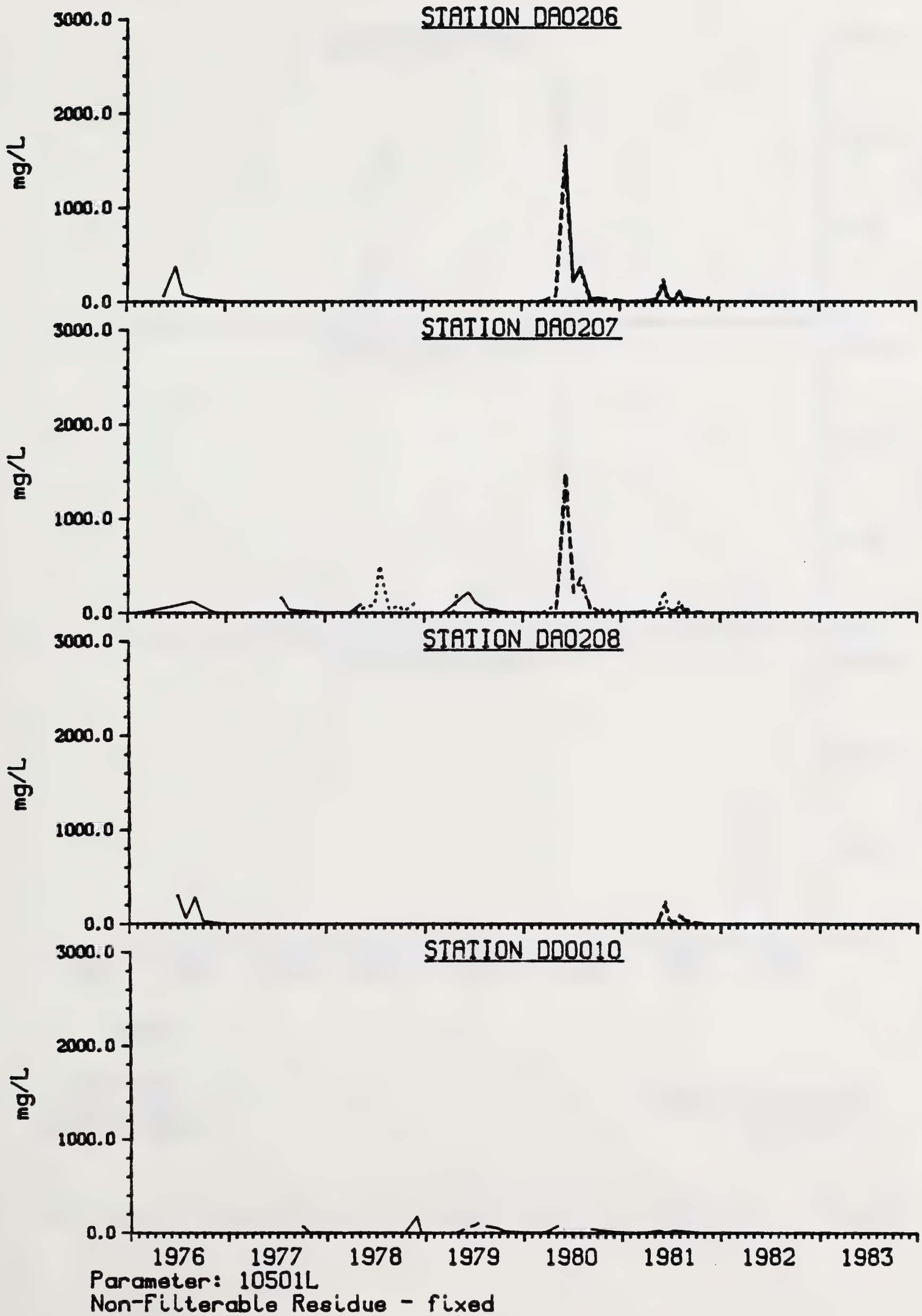


Figure 40. Non-filterable residue (fixed) at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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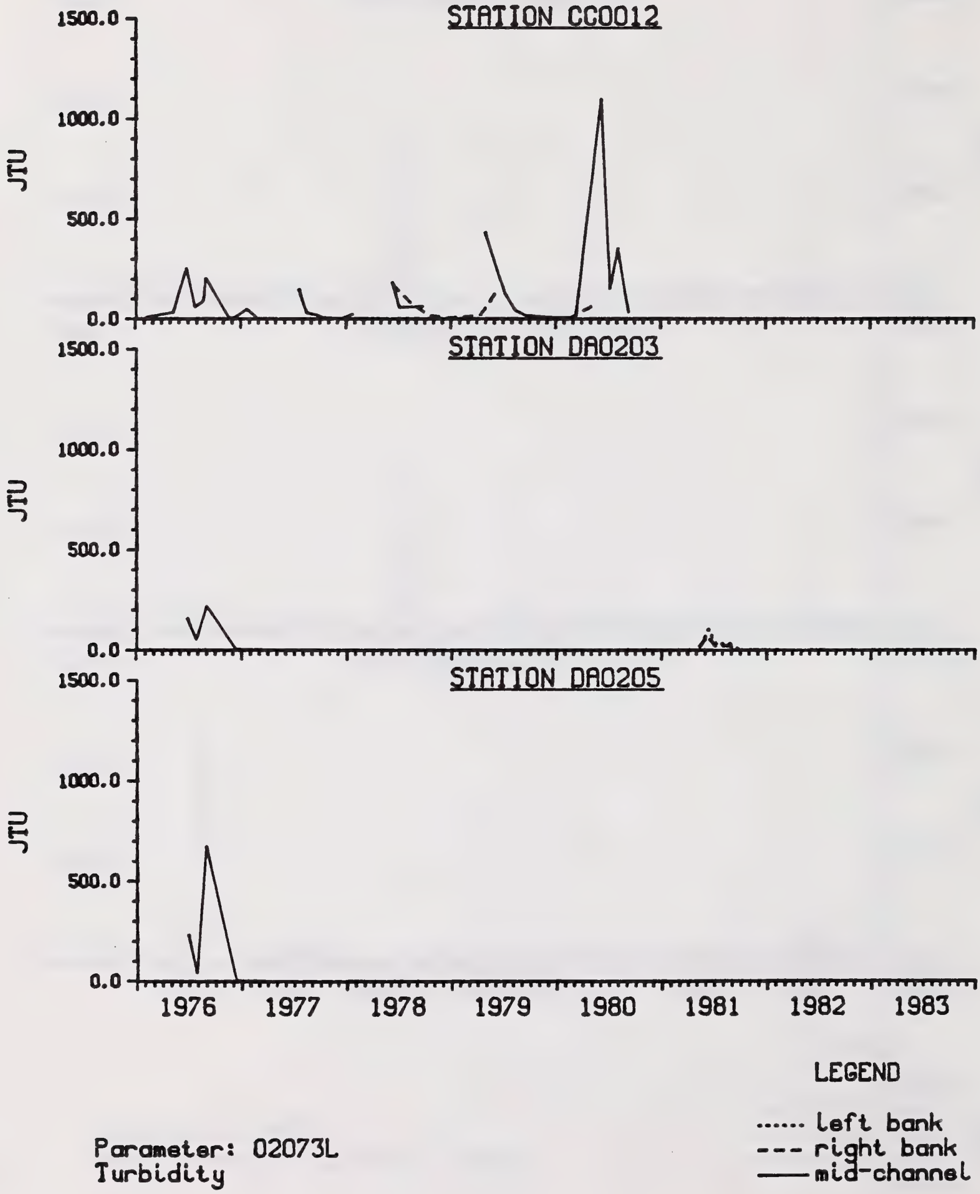
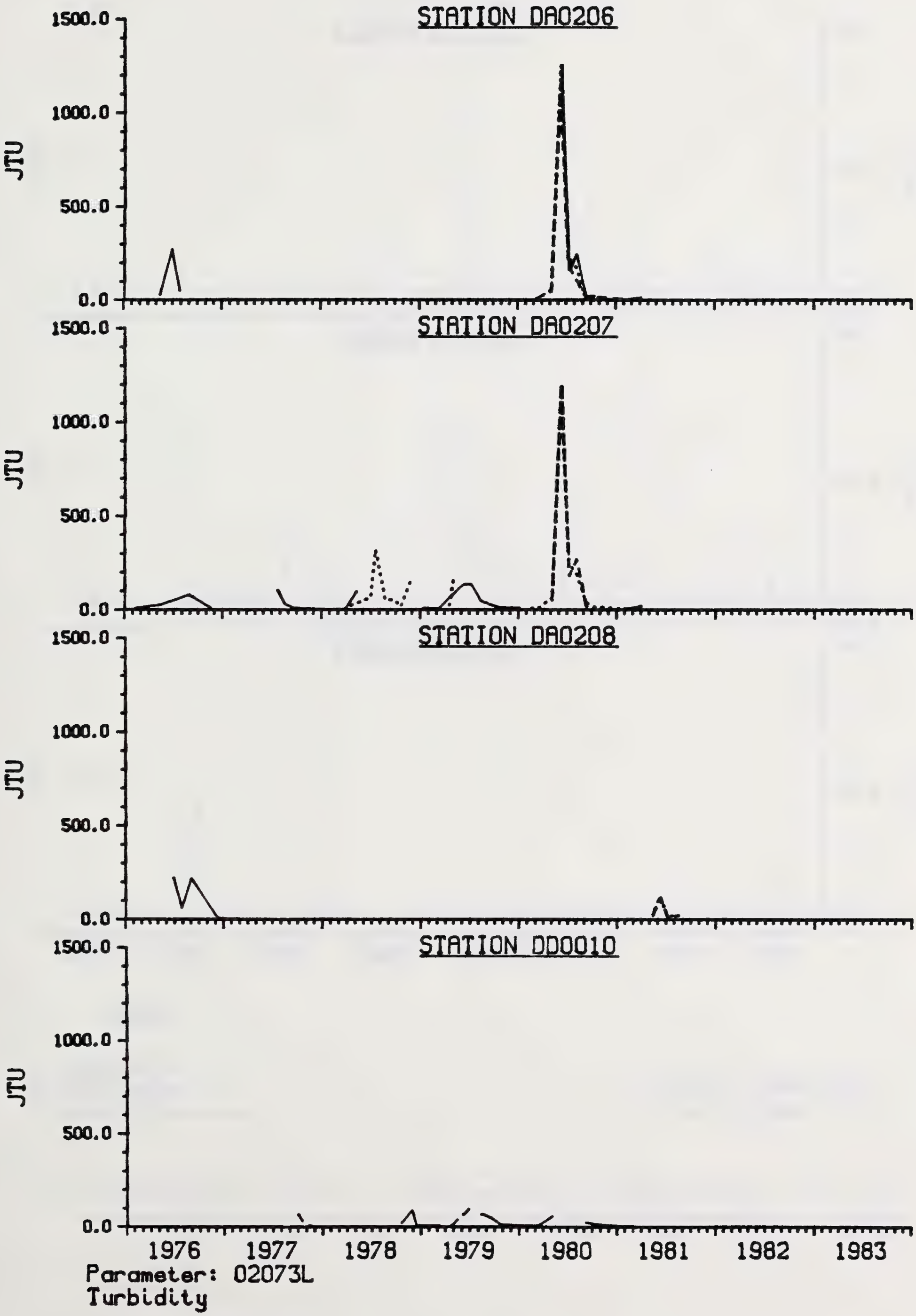


Figure 41. Turbidity at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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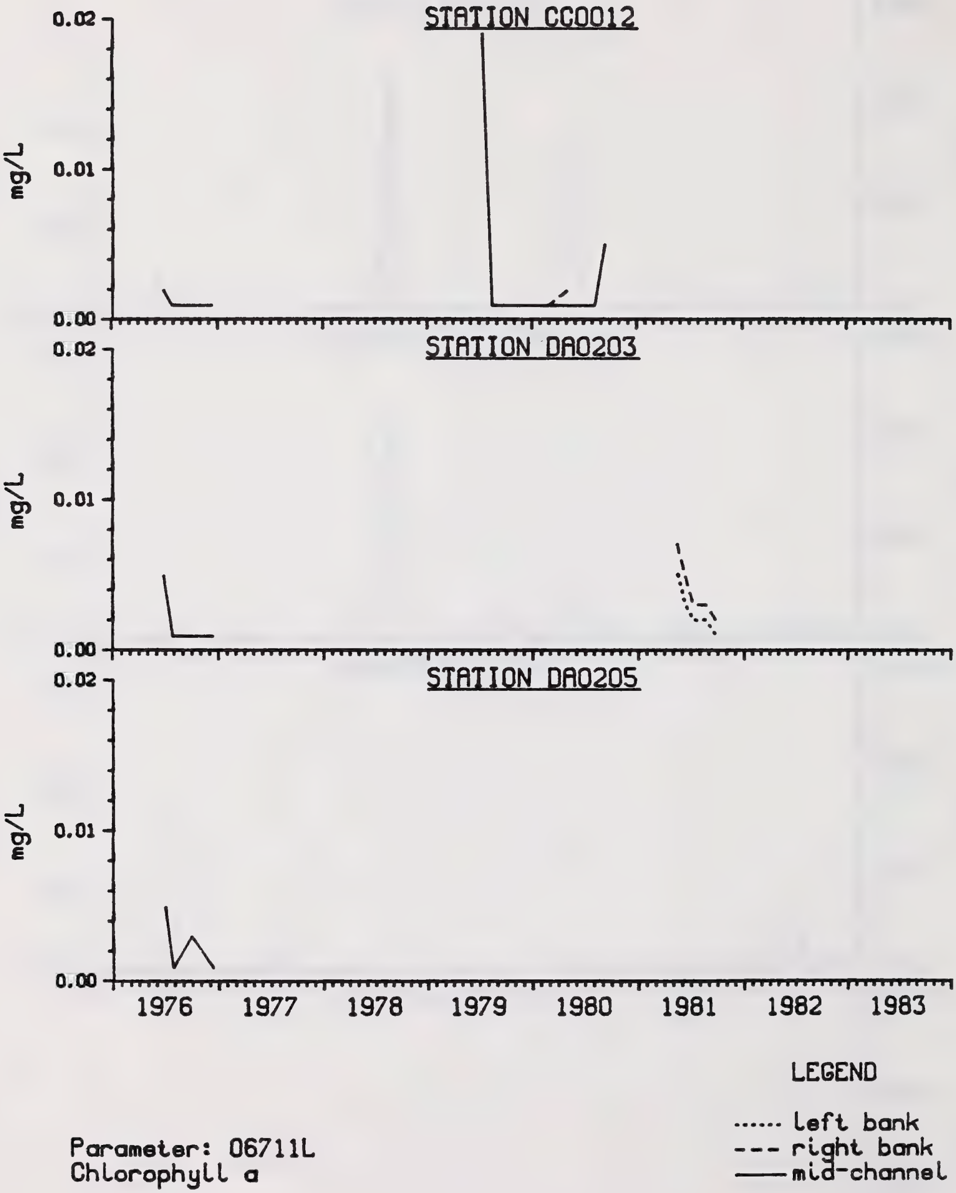
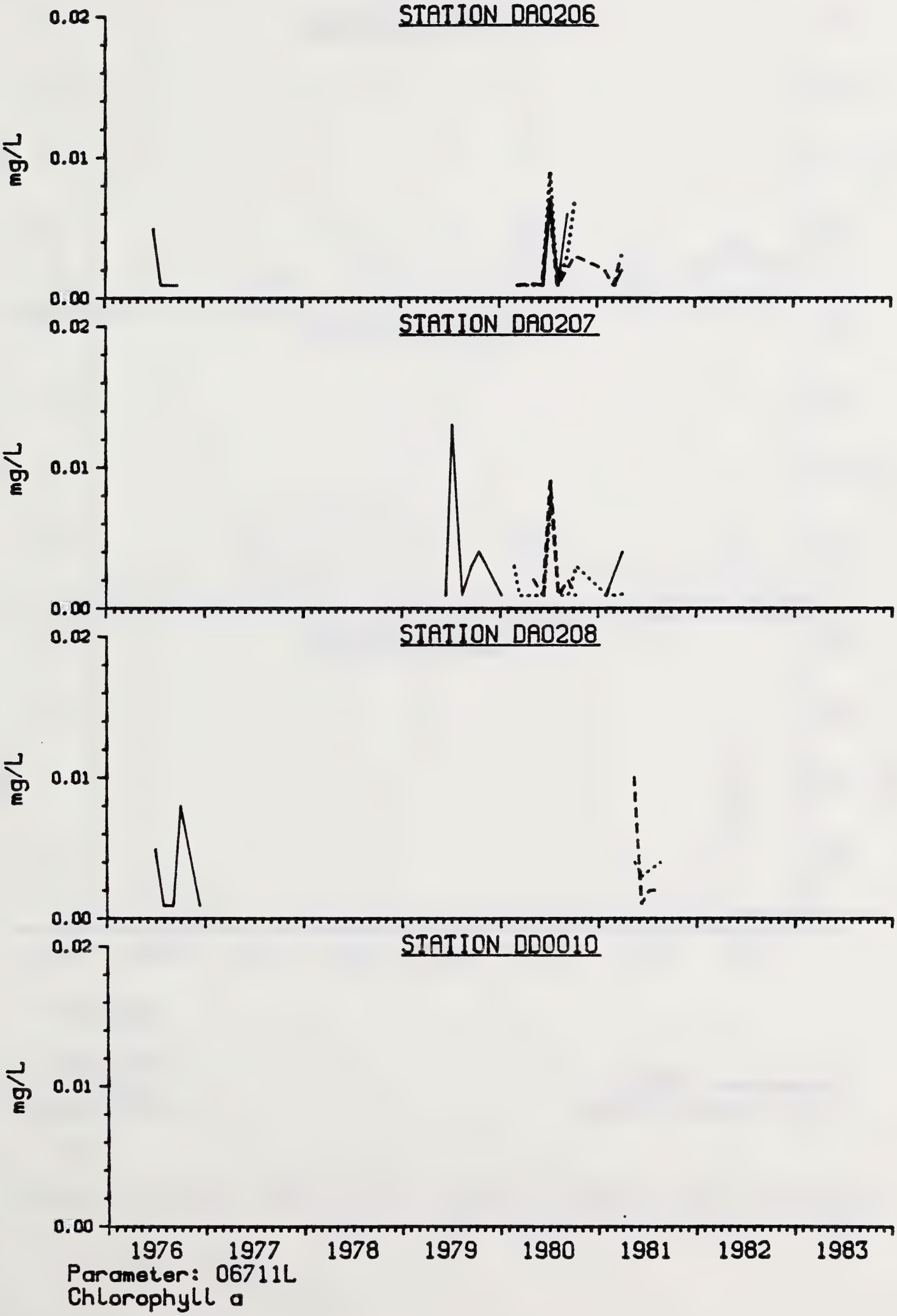


Figure 42. Chlorophyll a at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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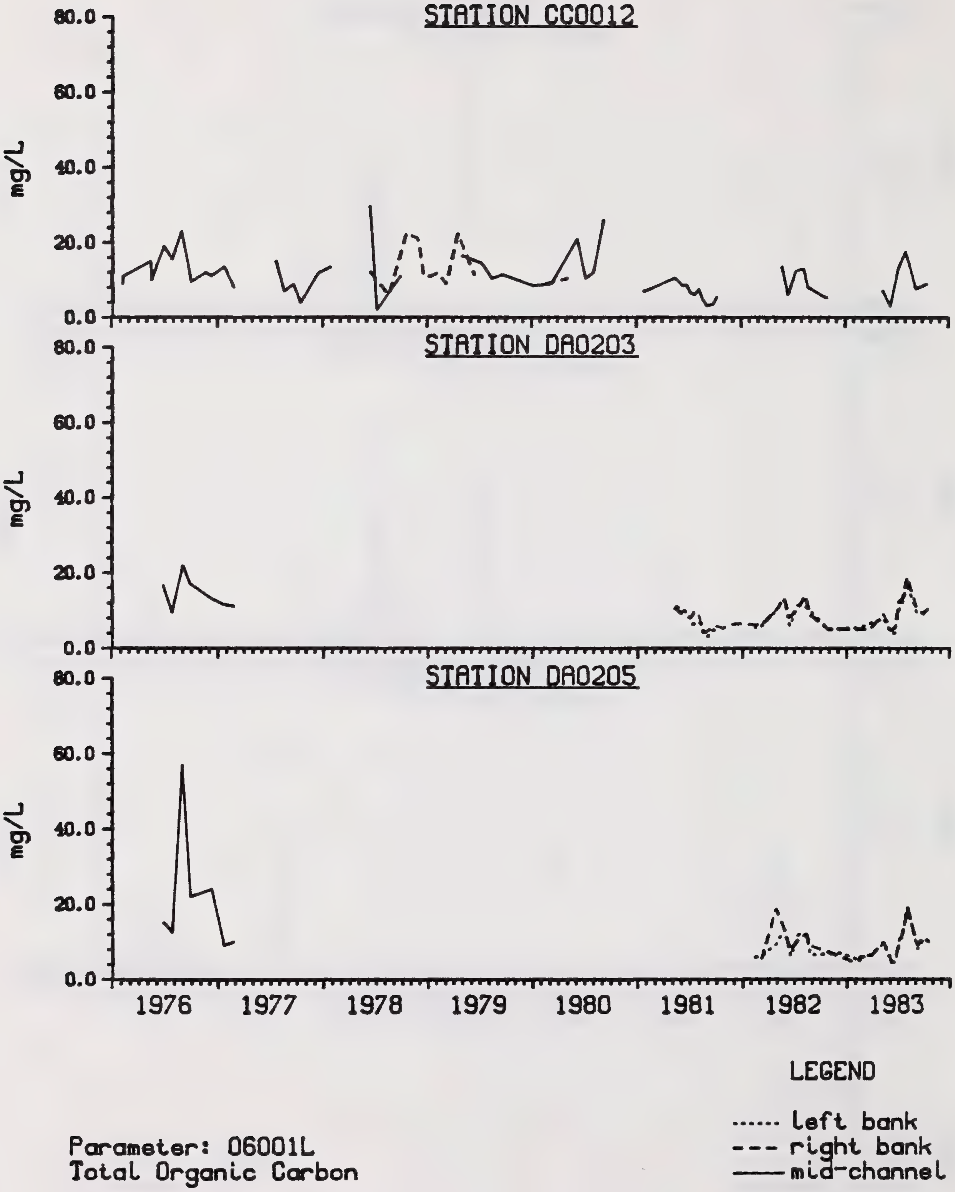
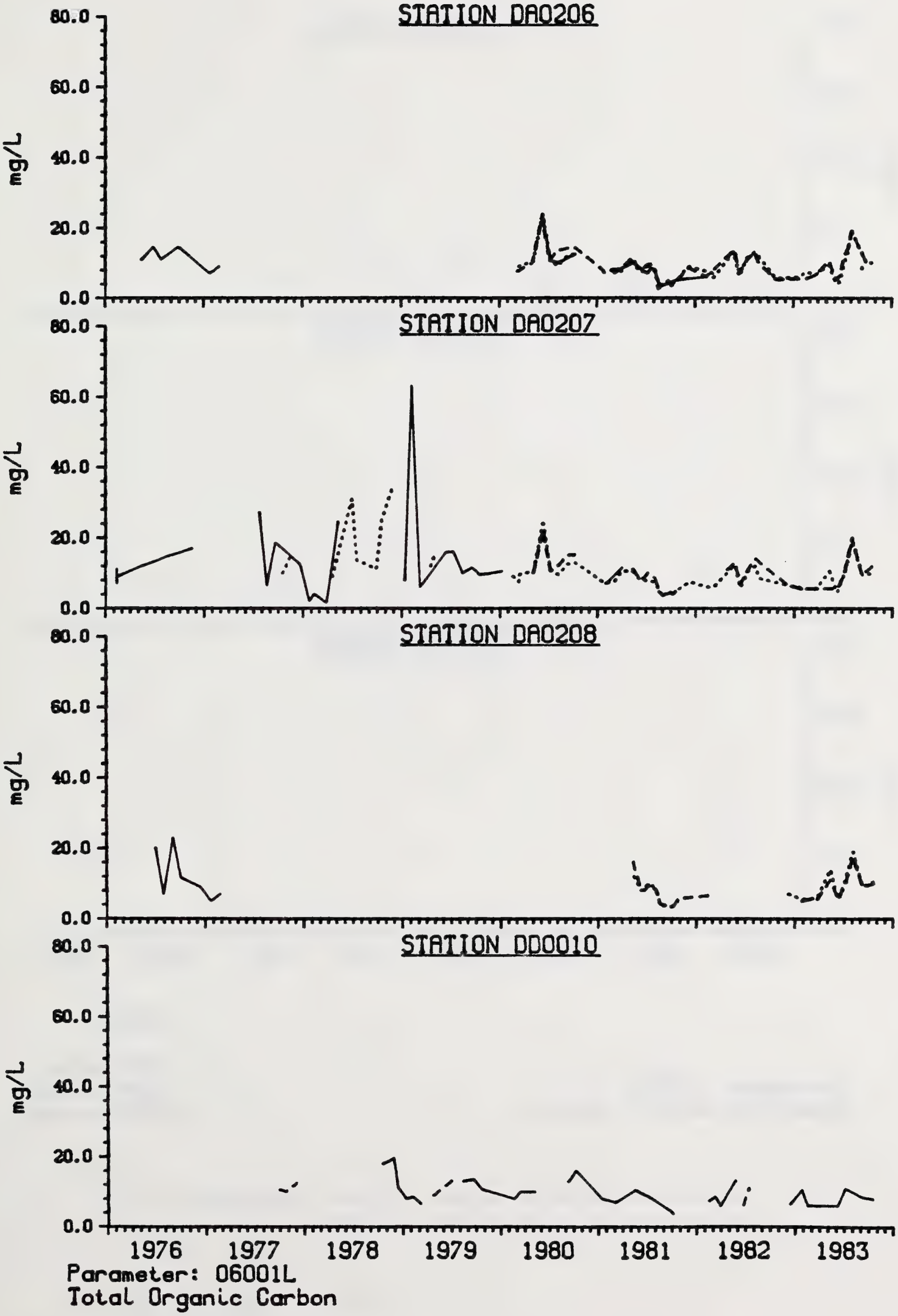


Figure 43. Total organic carbon at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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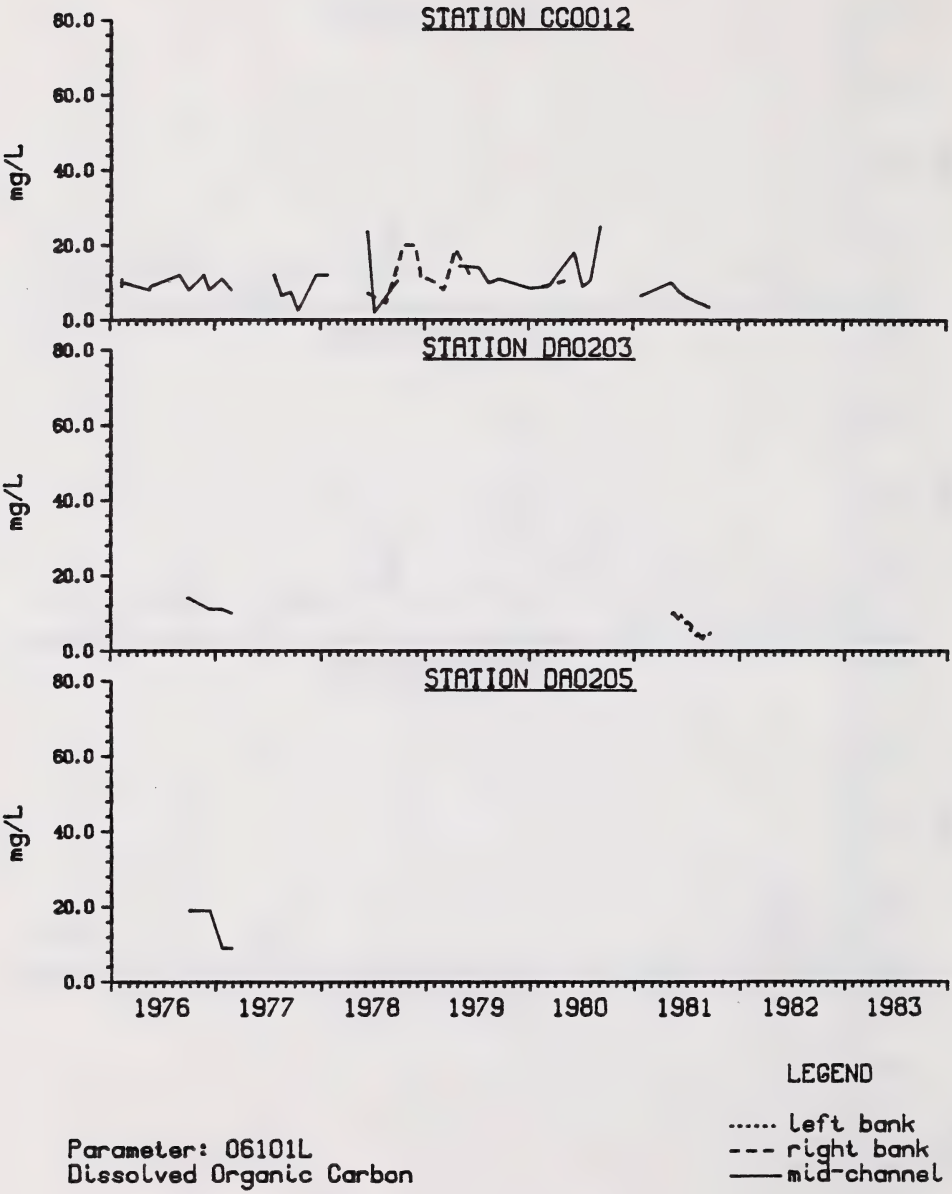
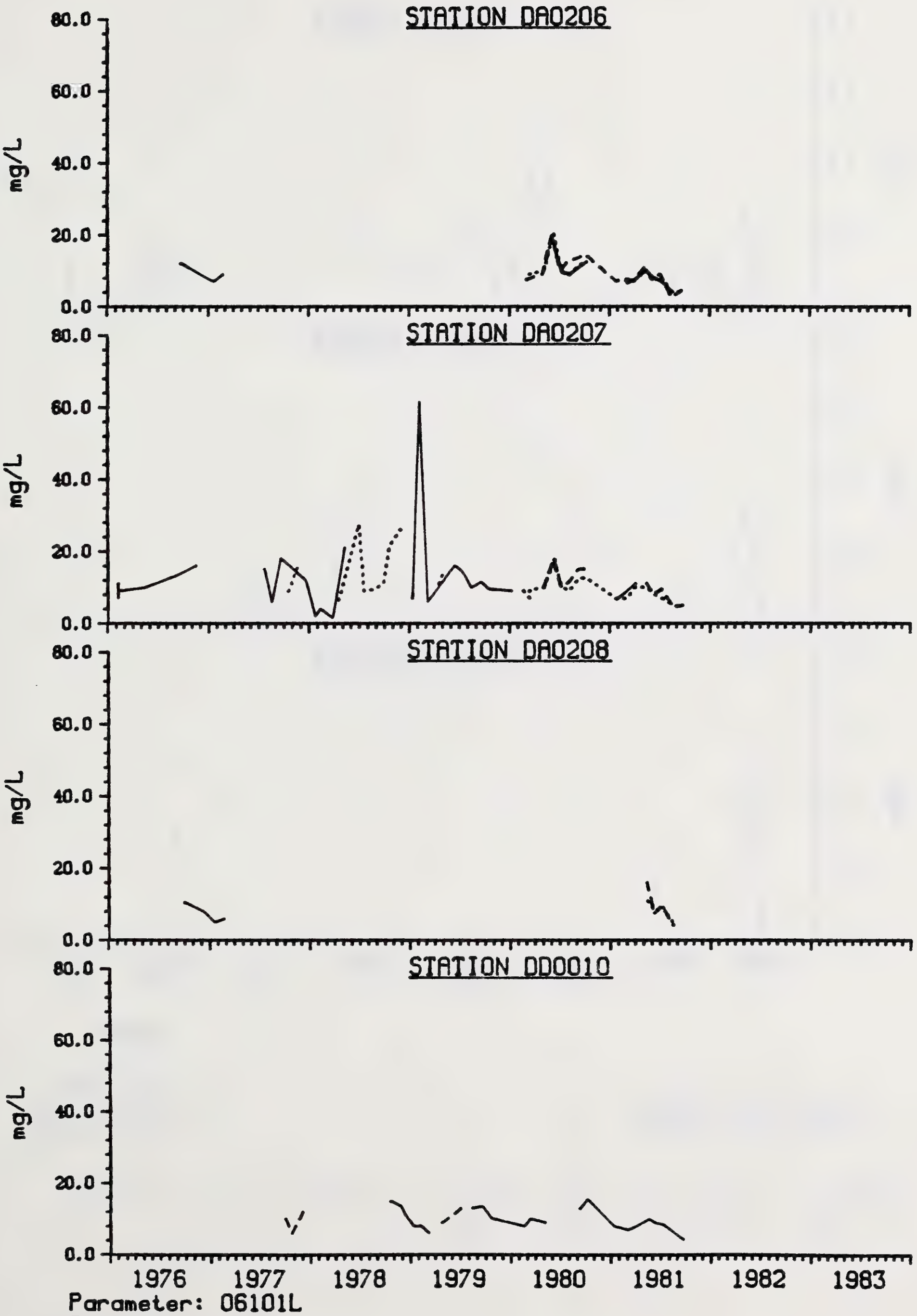


Figure 44. Dissolved organic carbon at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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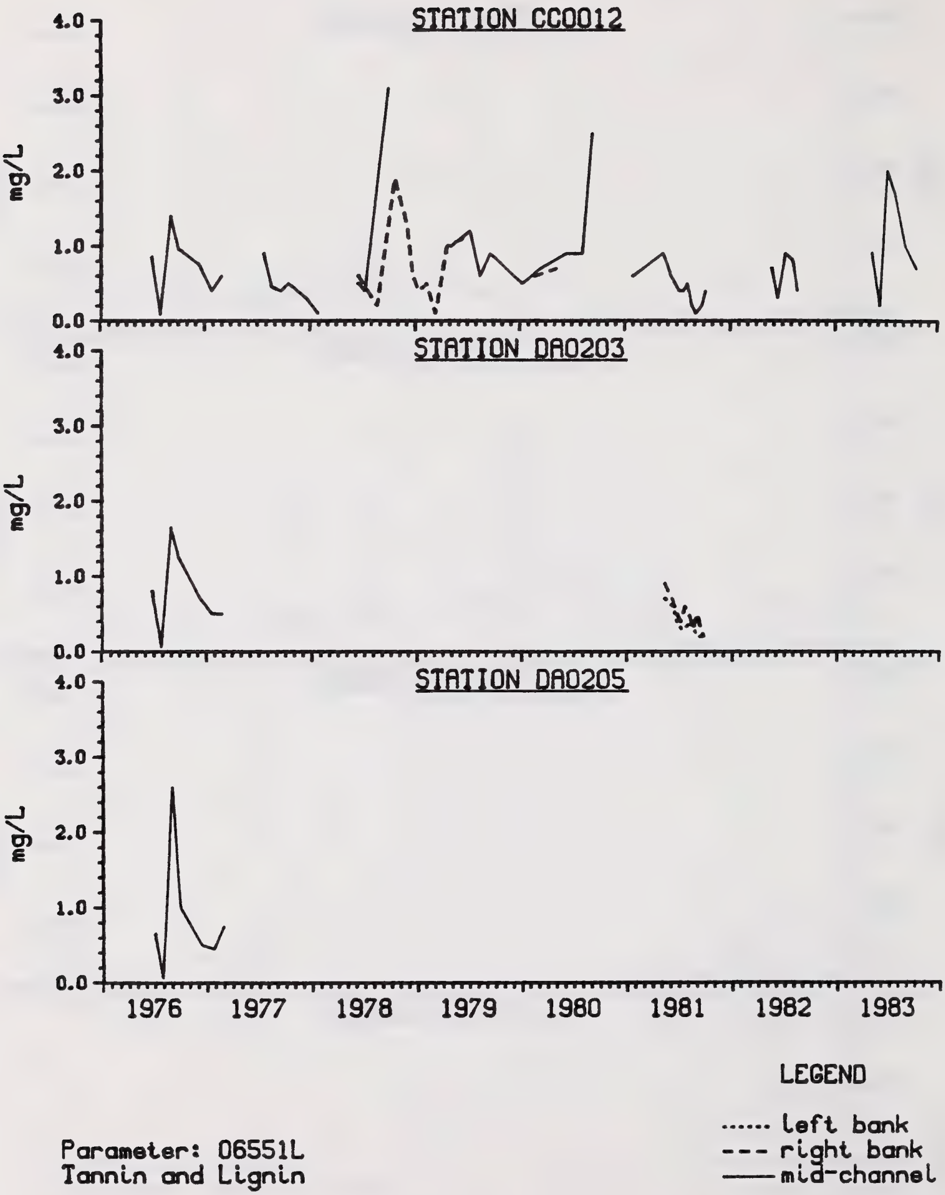
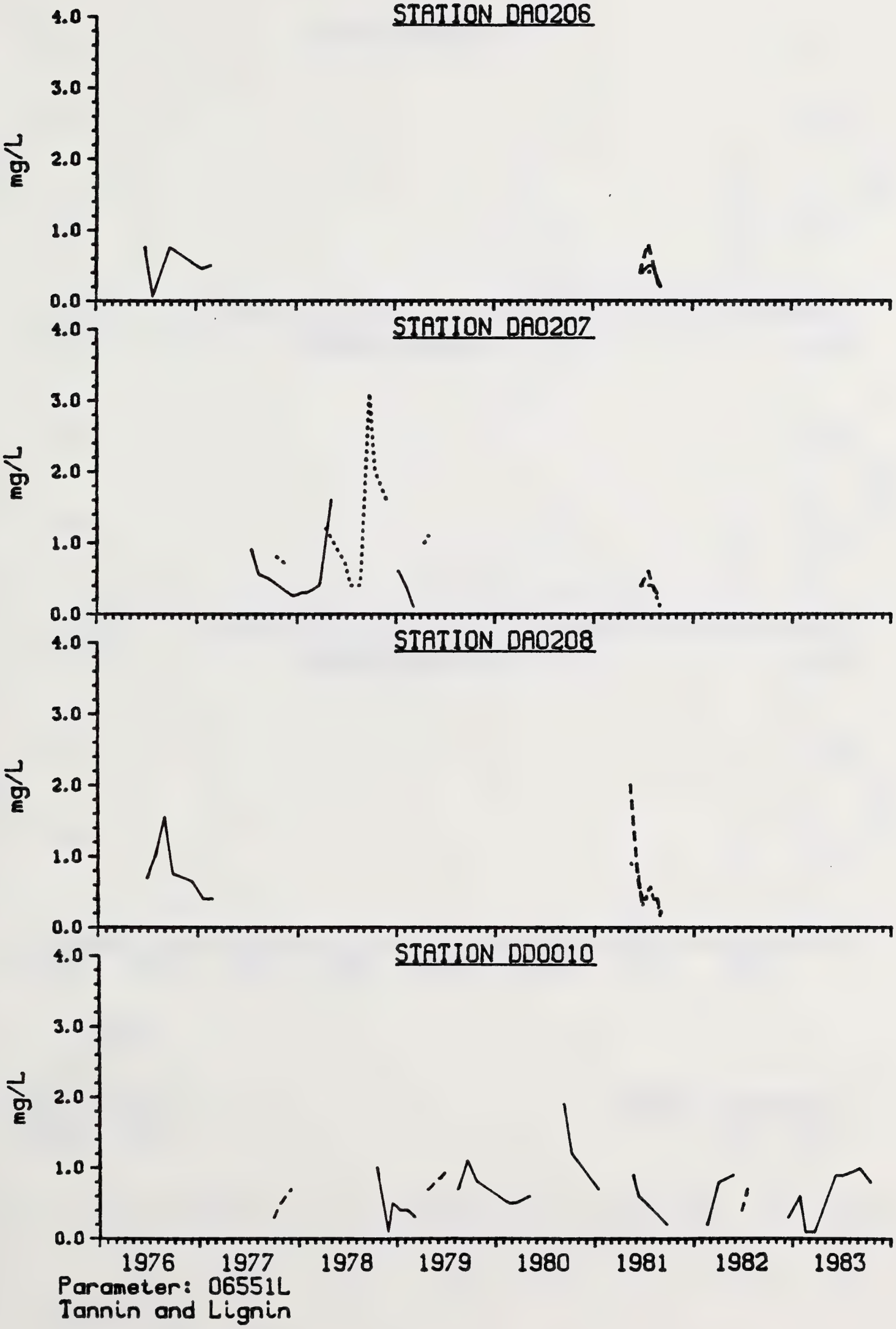


Figure 45. Tannin and lignin at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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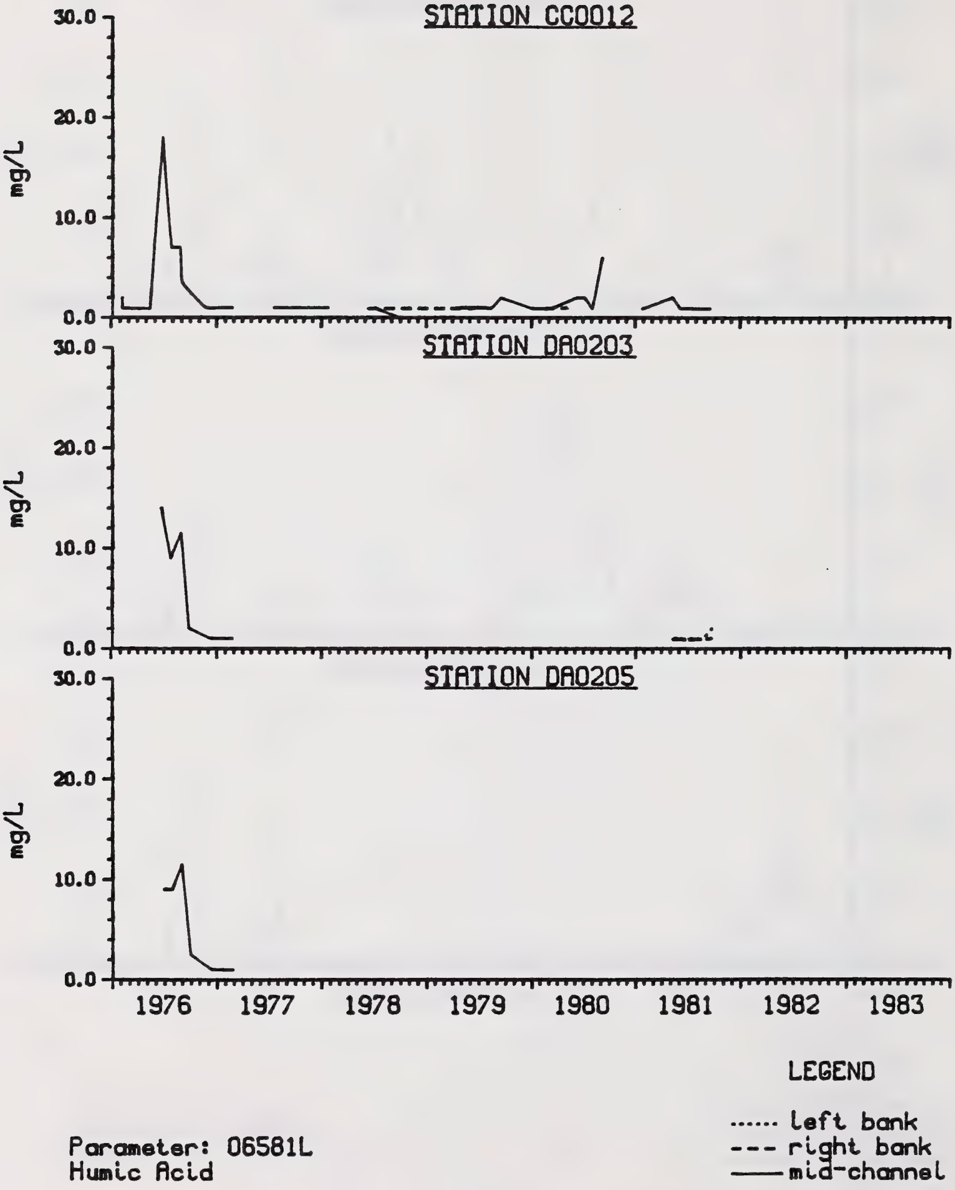
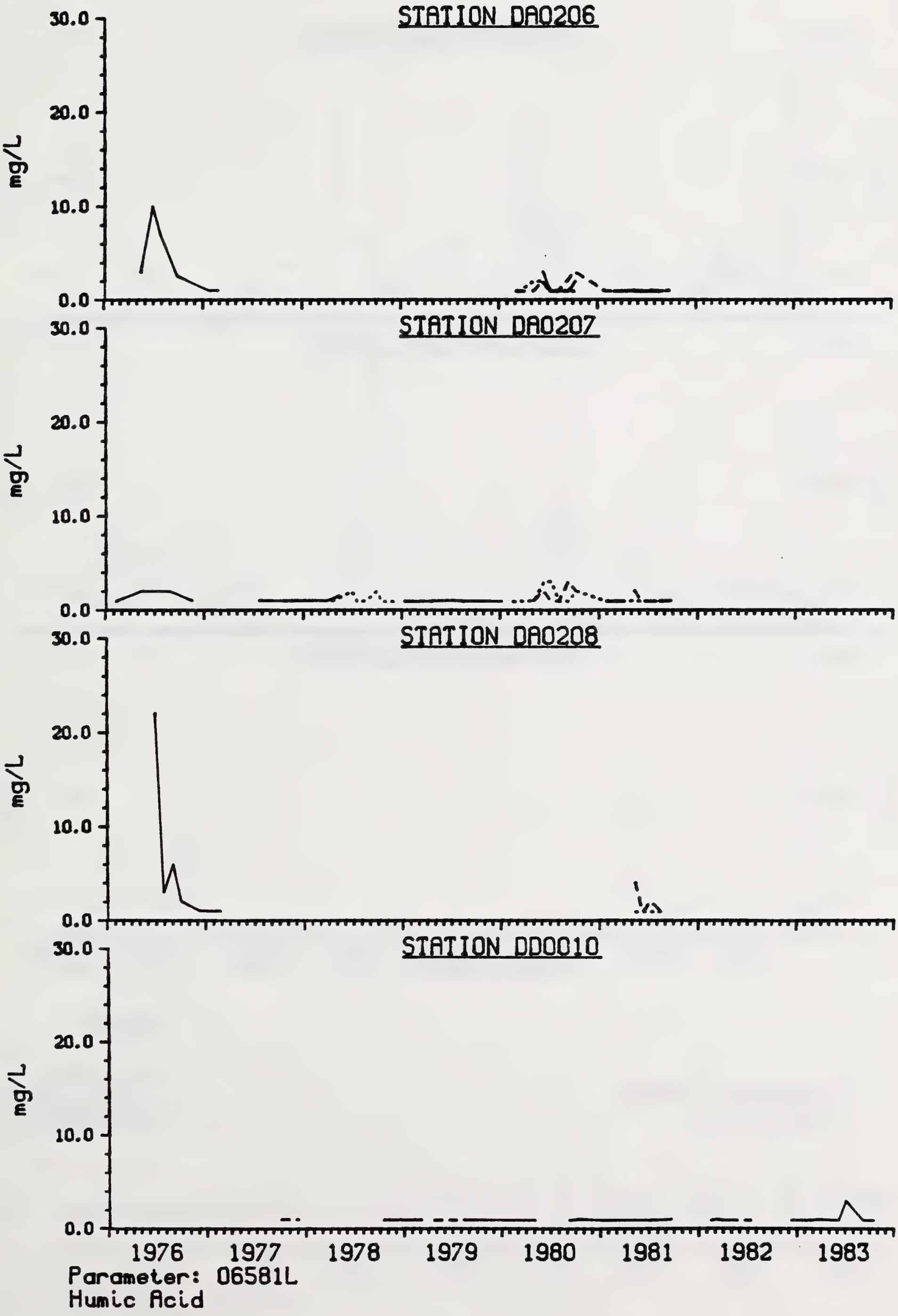


Figure 46. Humic acid at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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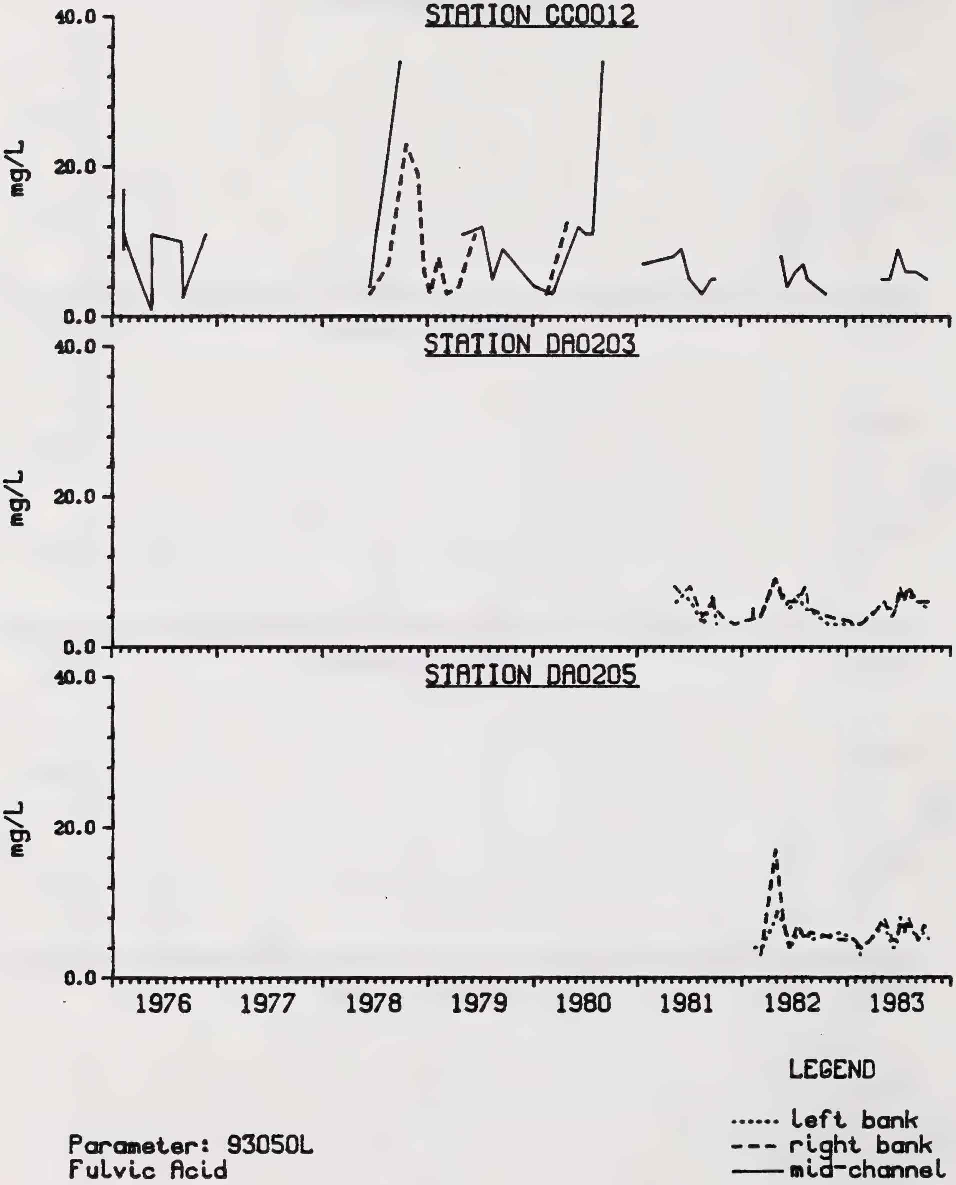
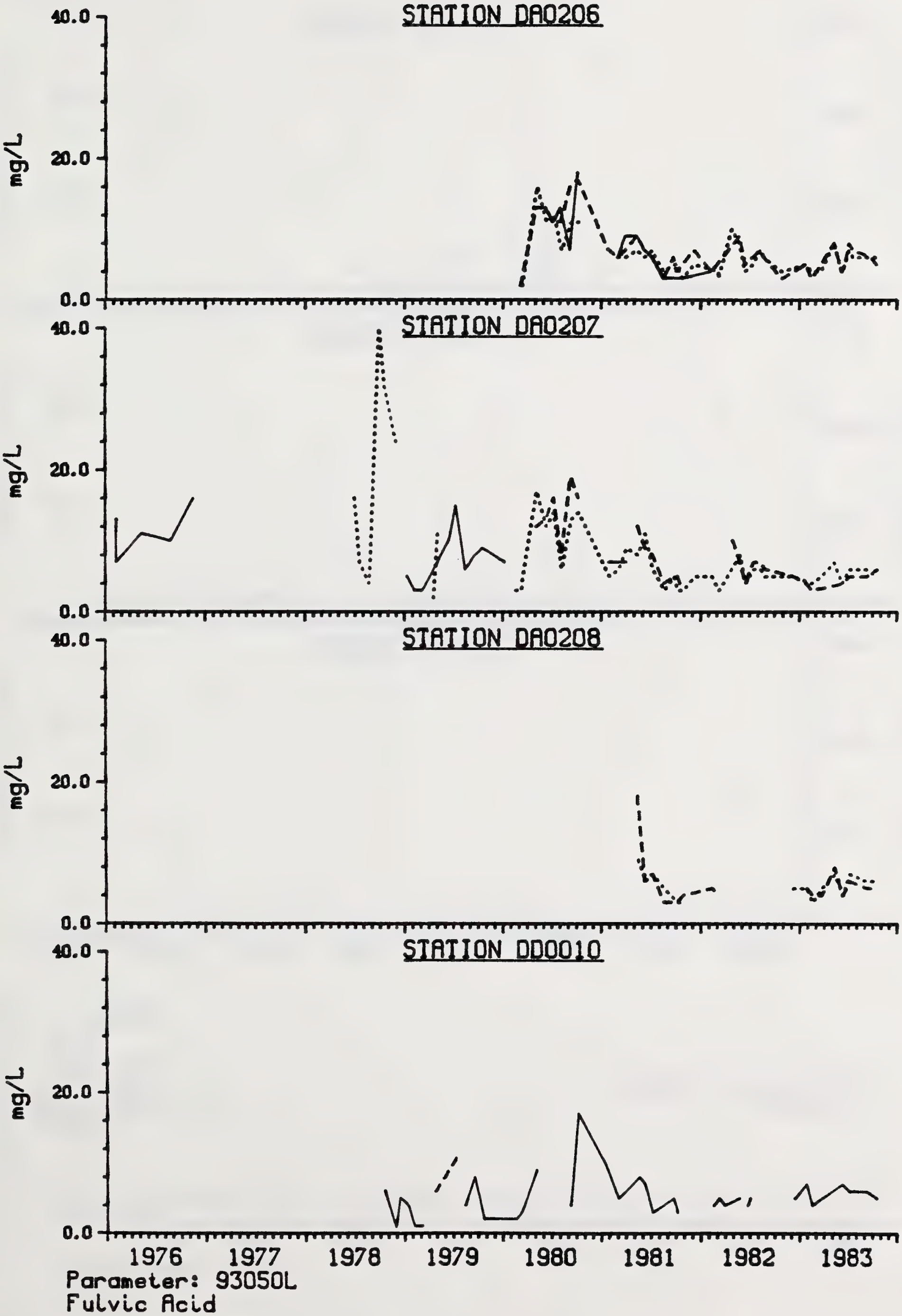


Figure 47. Fulvic acid at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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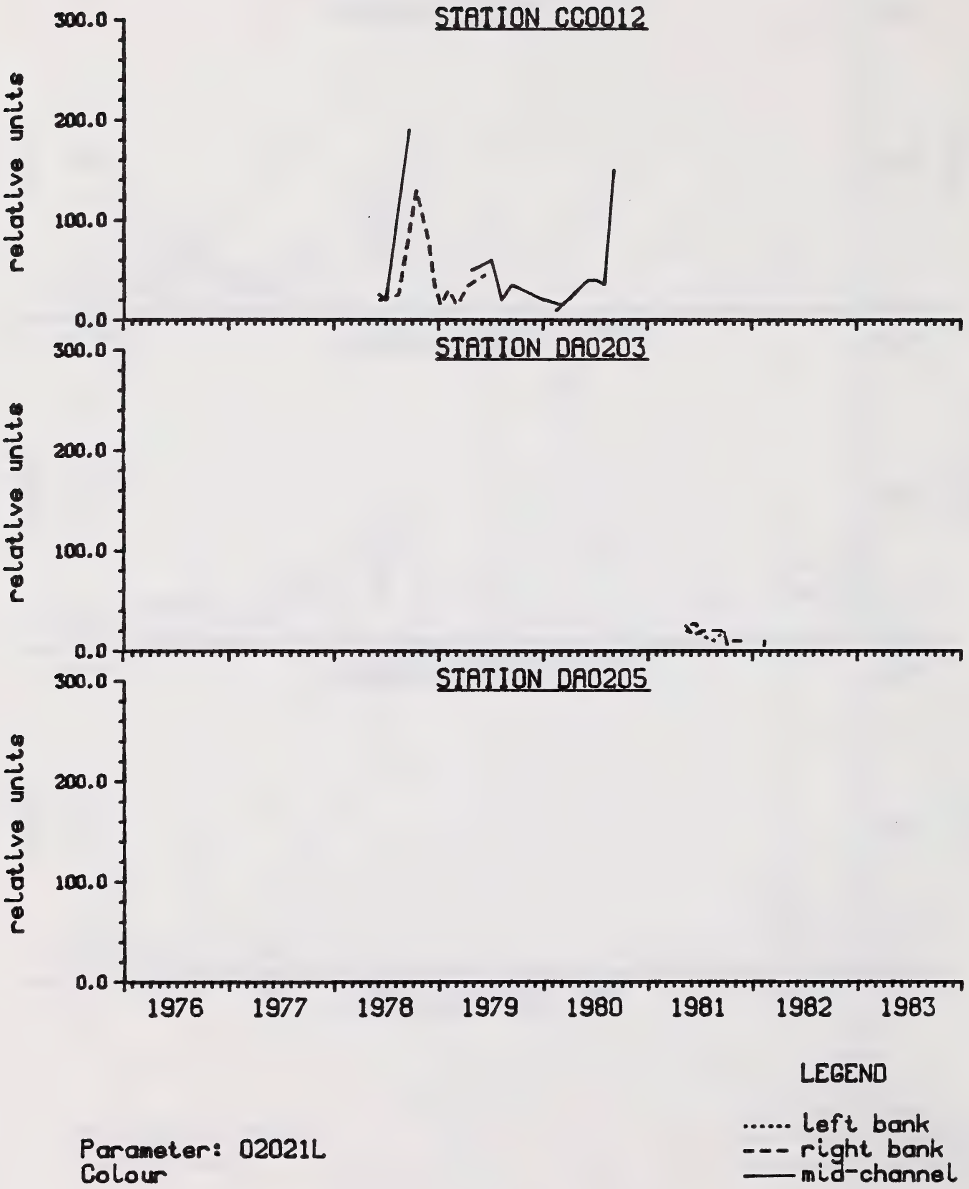
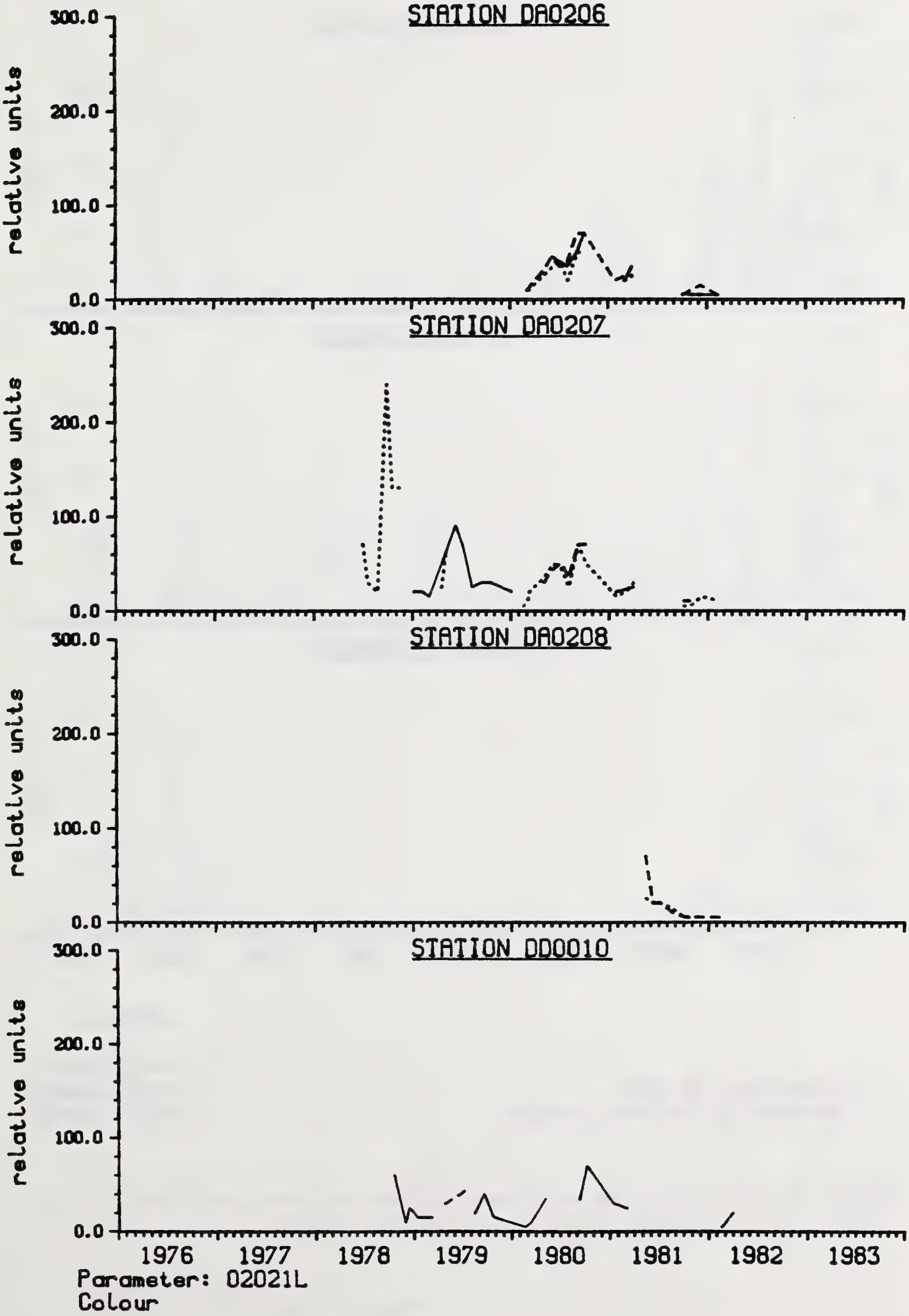


Figure 48. Water colour at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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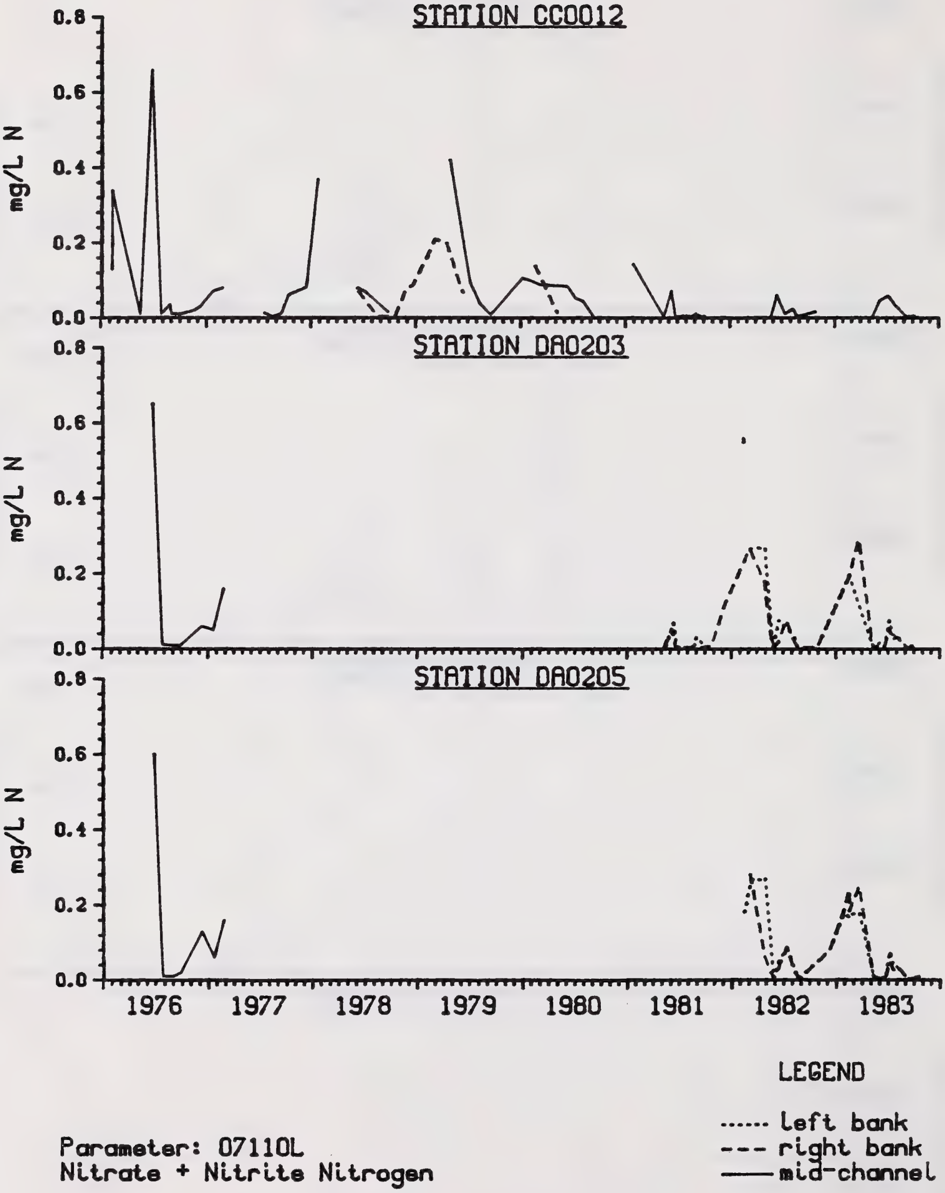
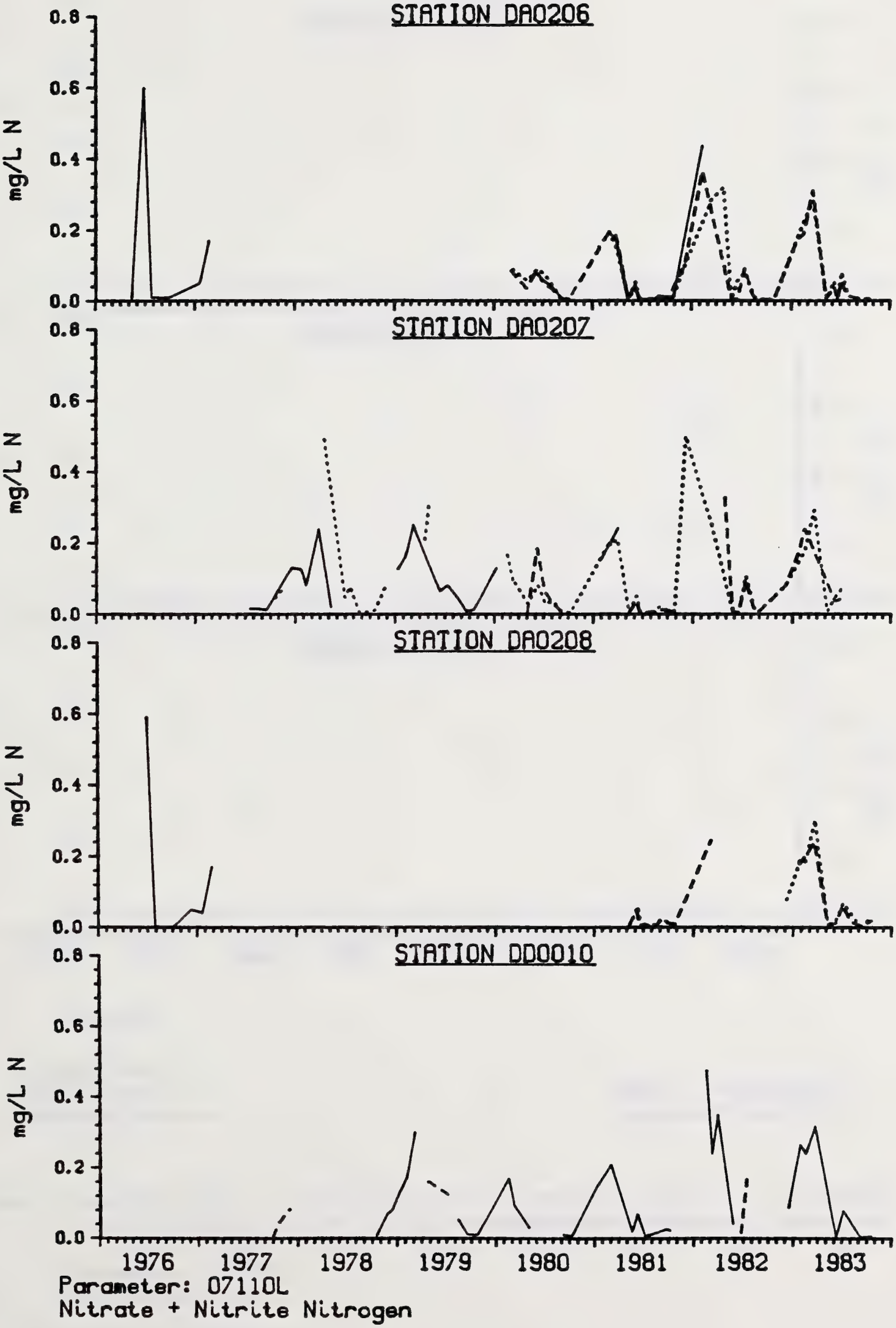


Figure 49. Nitrate plus nitrite nitrogen at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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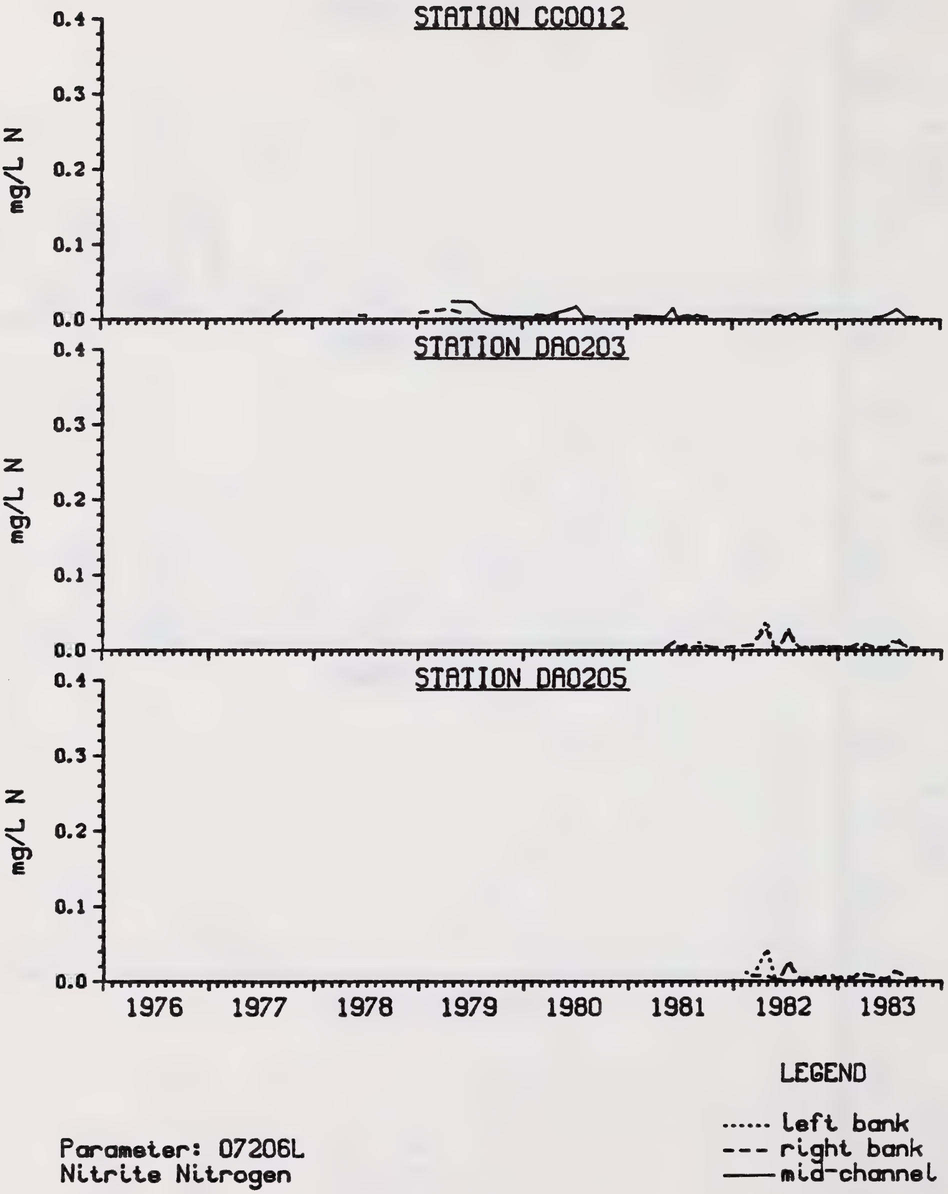
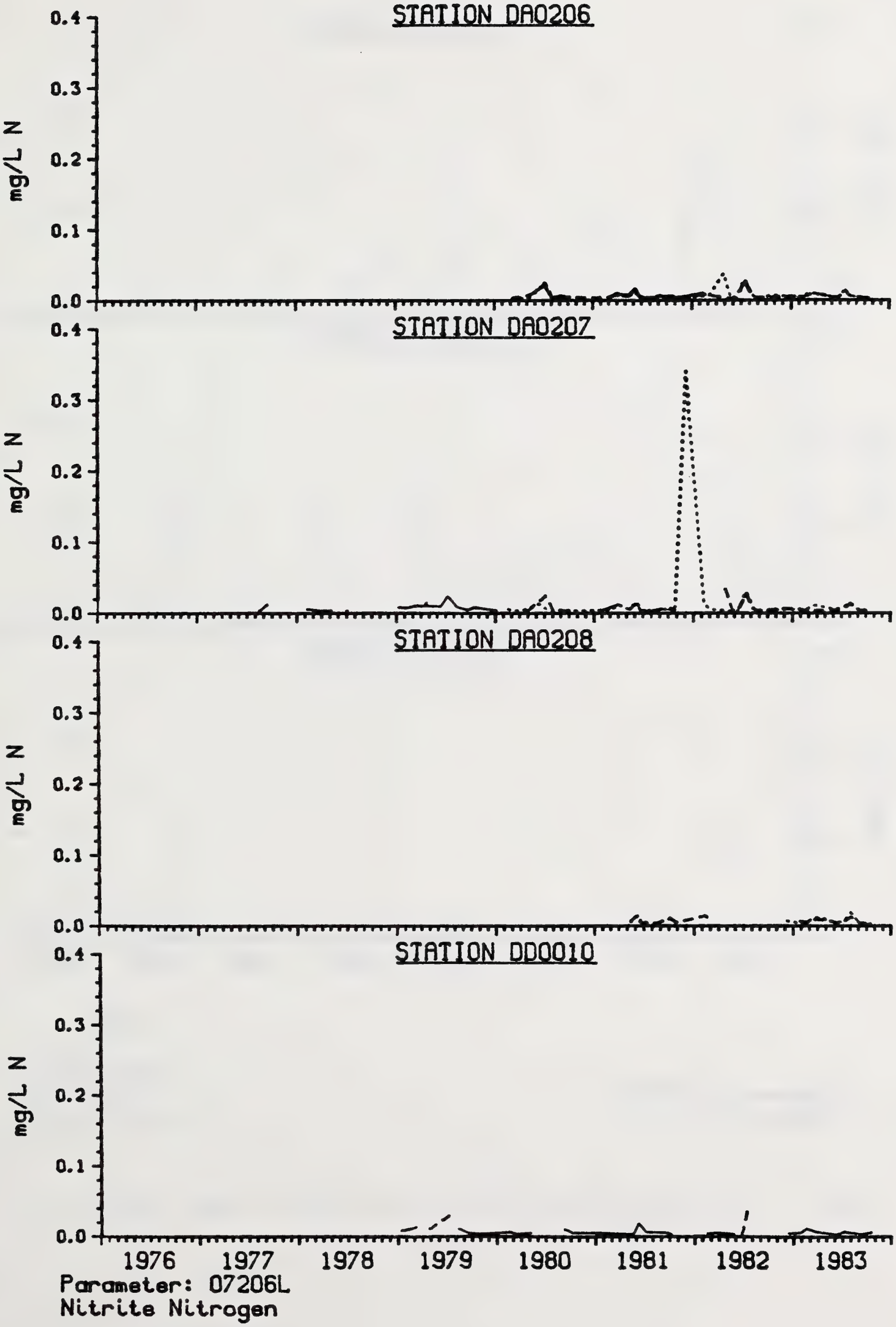


Figure 50. Nitrite nitrogen at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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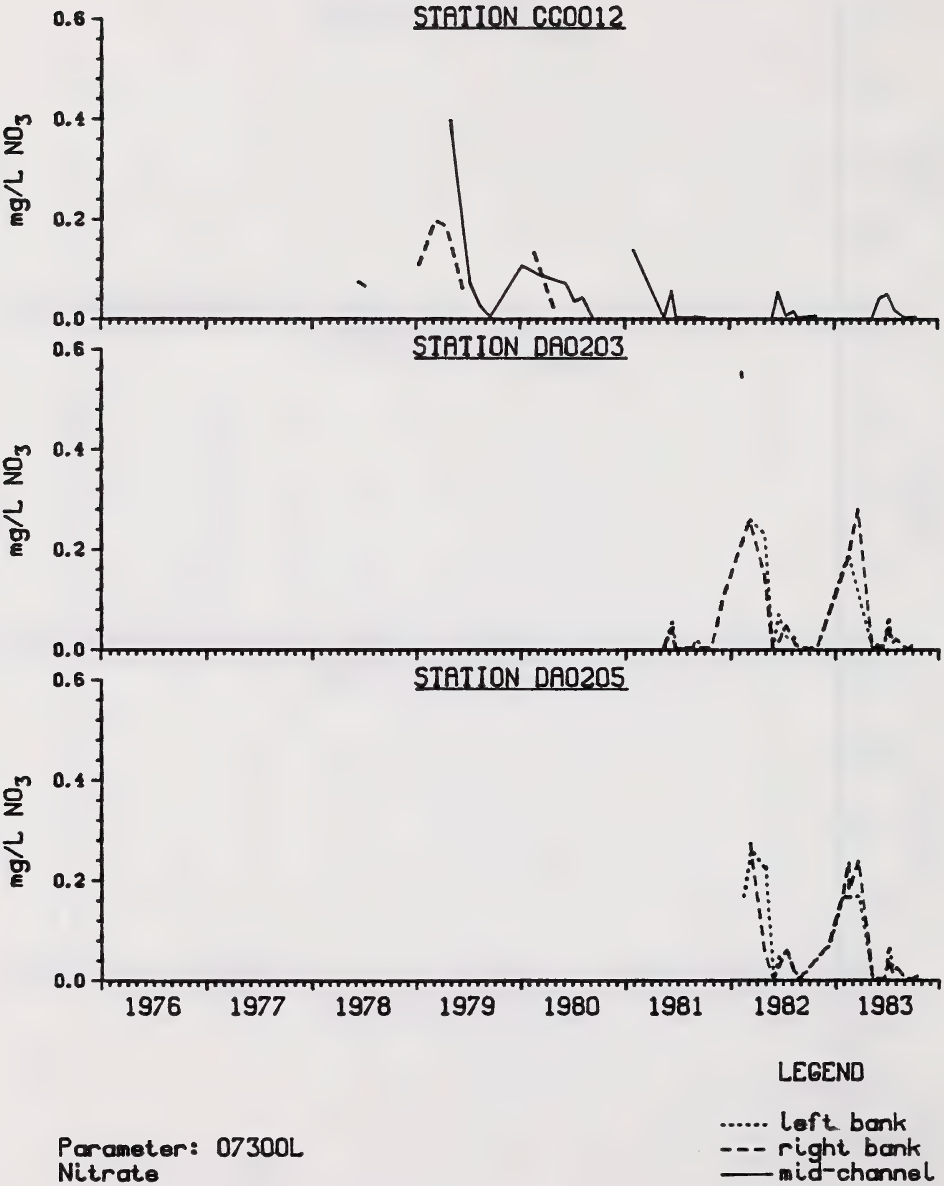
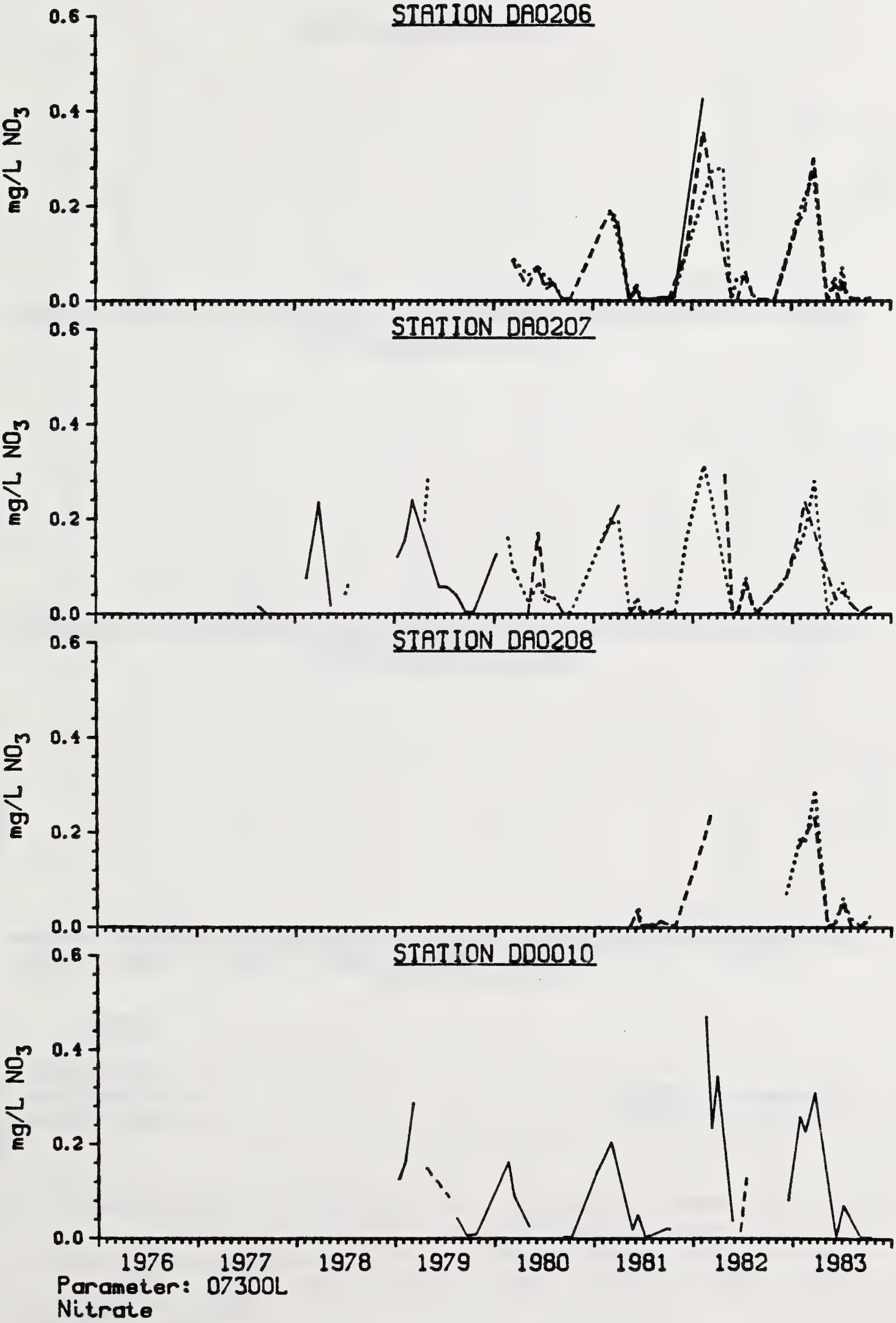


Figure 51. Nitrate at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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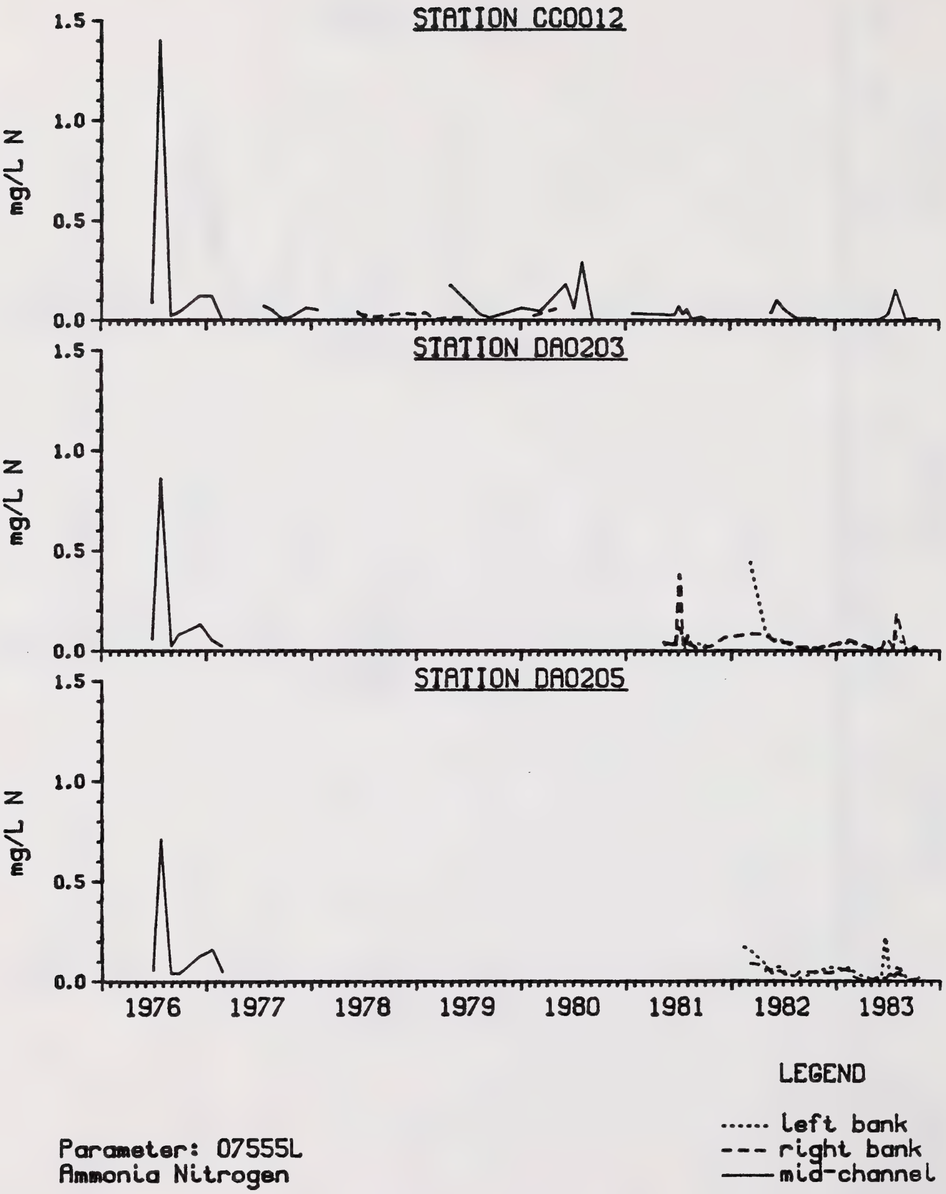
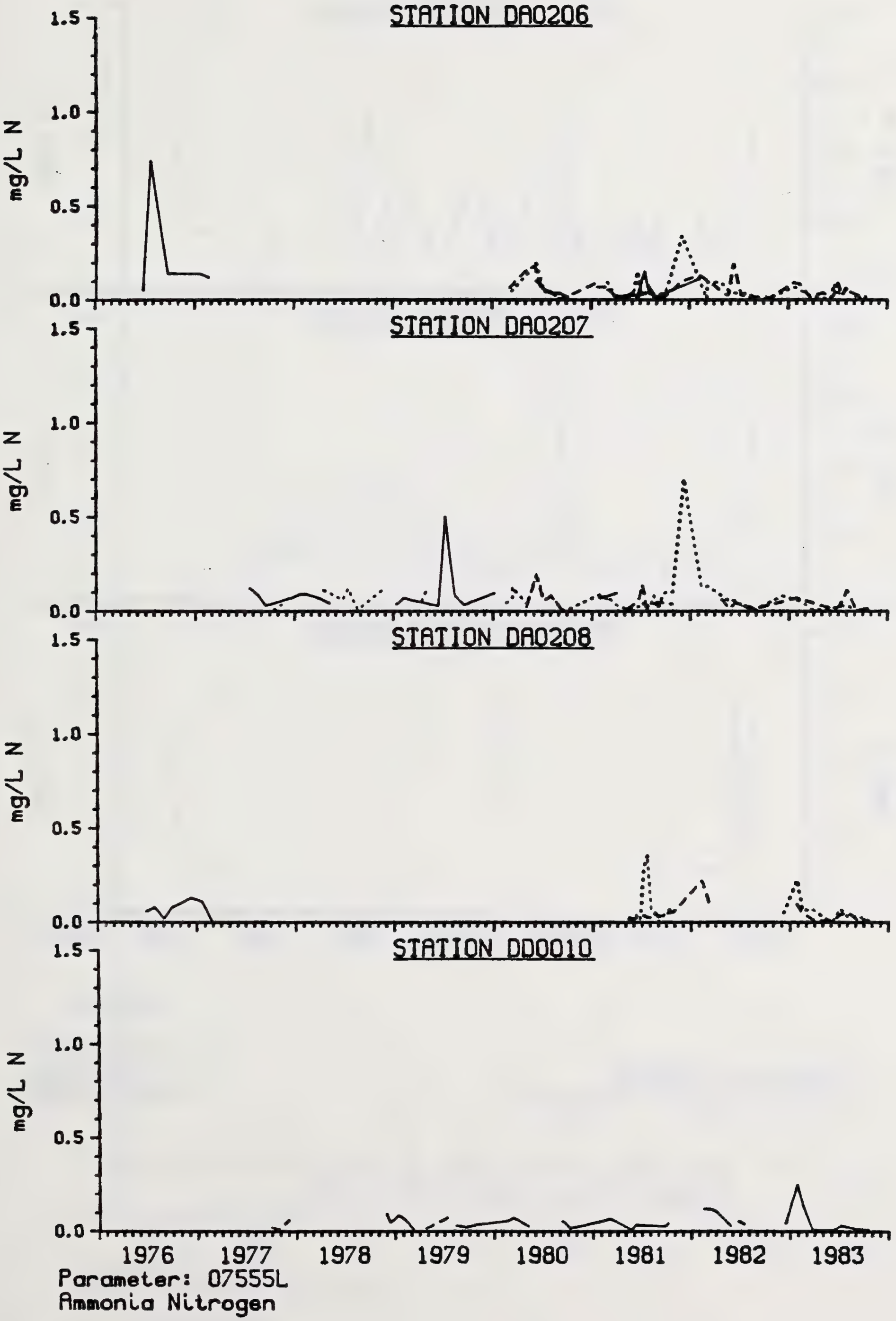


Figure 52. Ammonia nitrogen at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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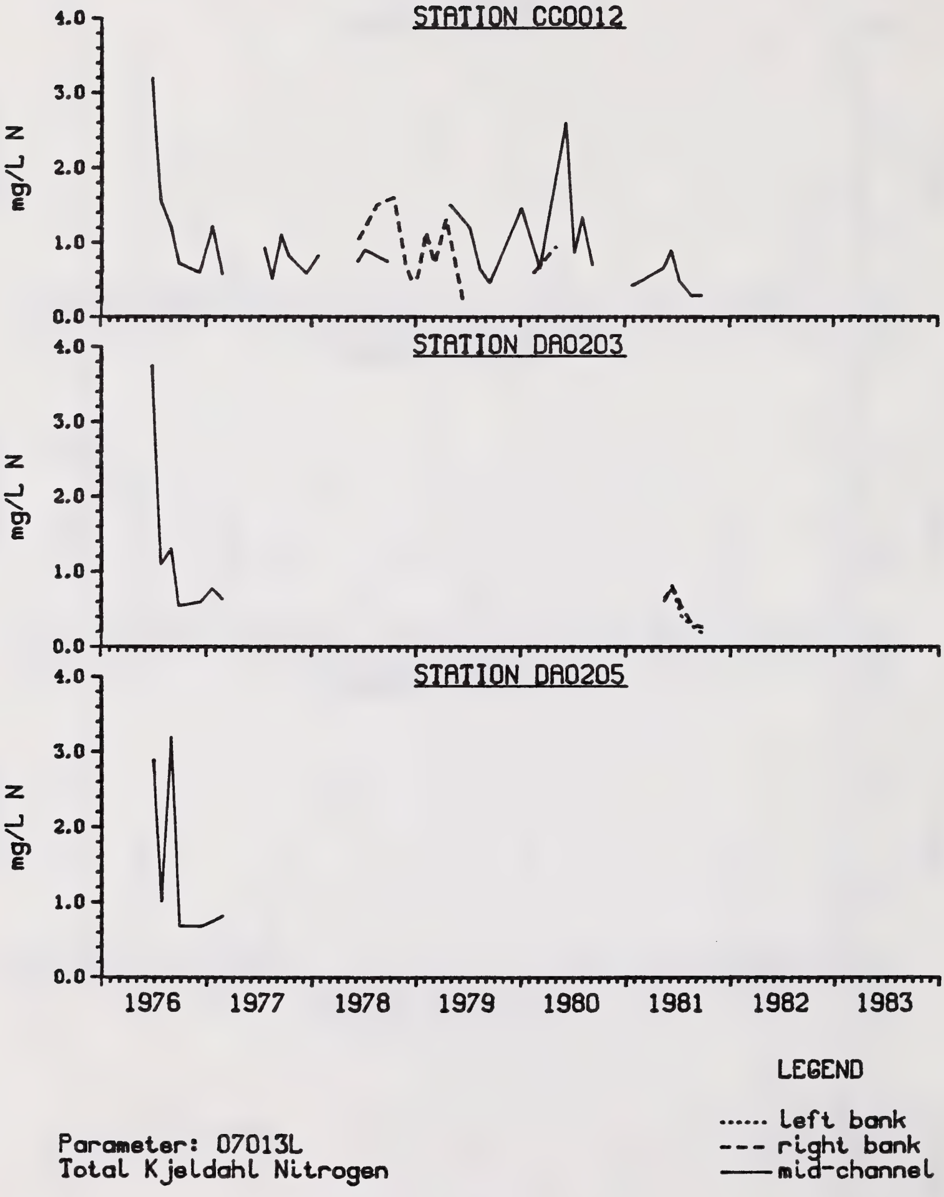
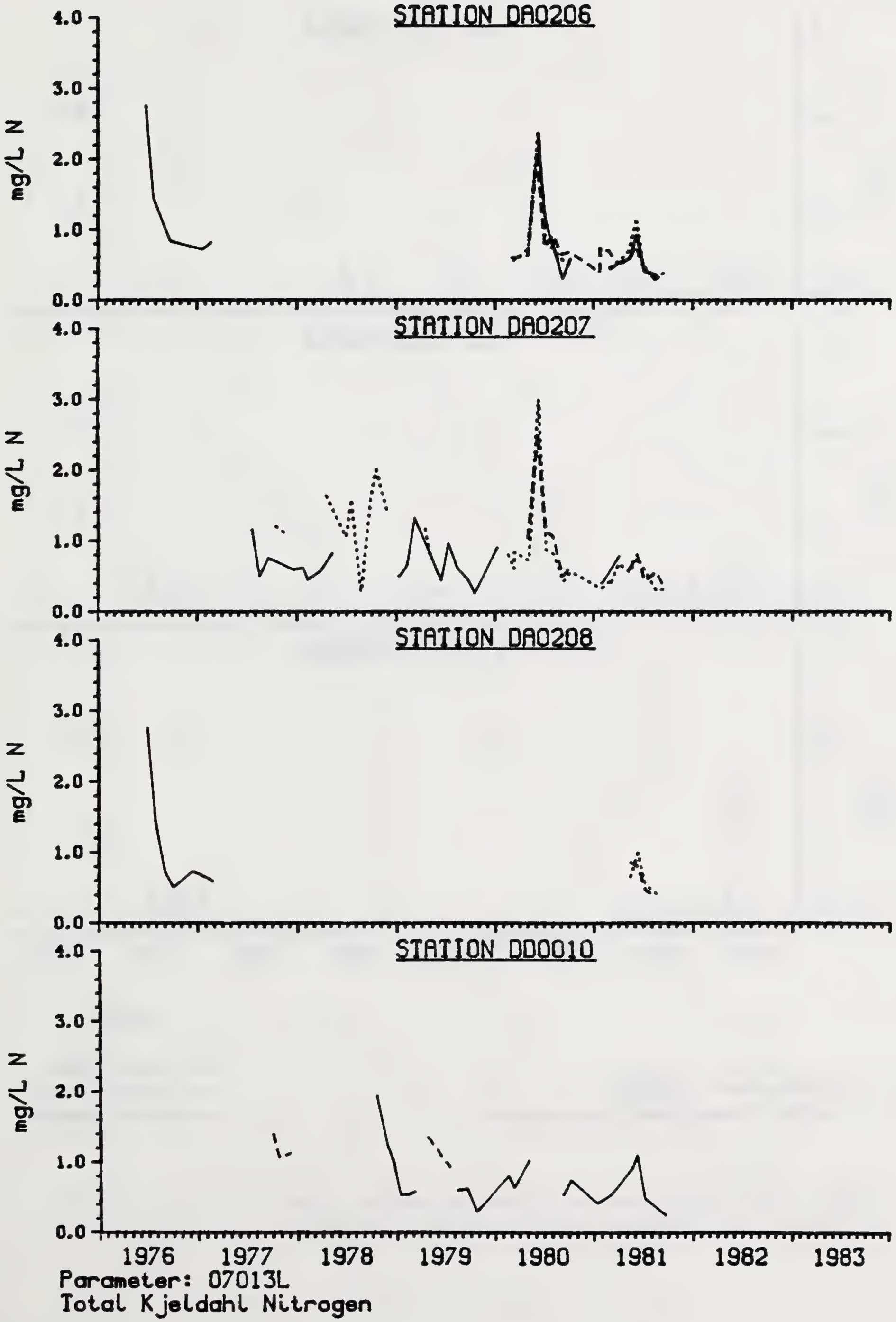


Figure 53. Total Kjeldahl nitrogen at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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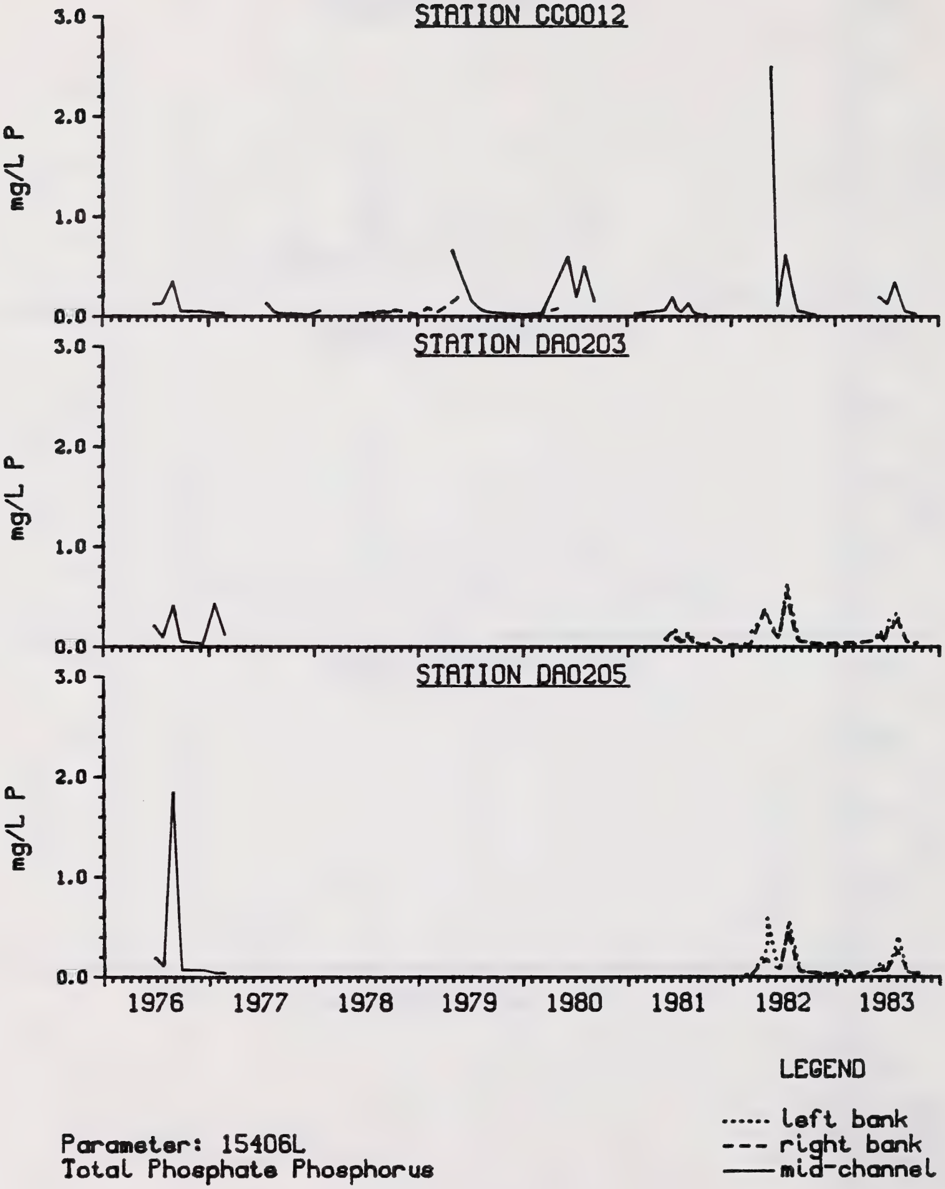
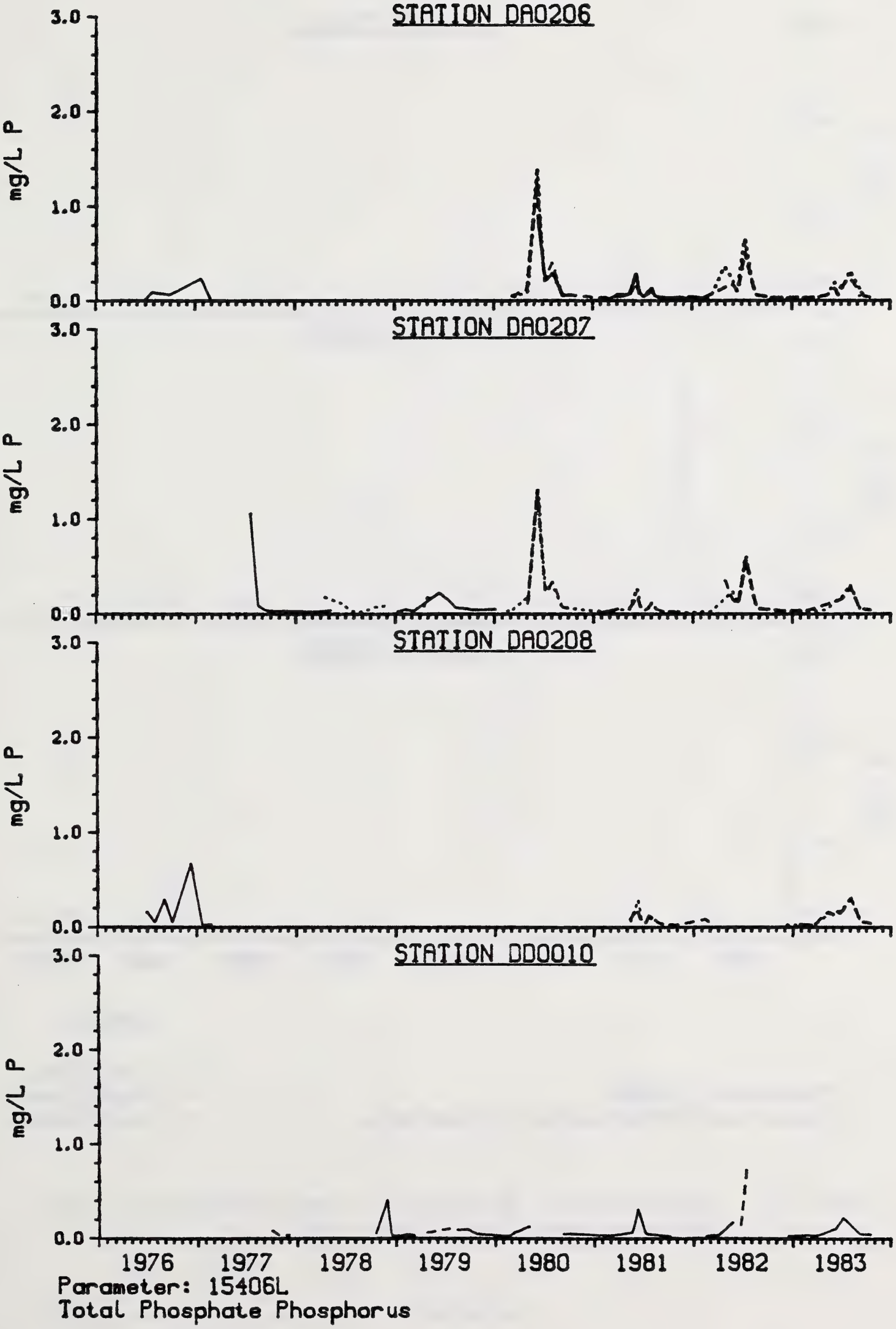


Figure 54. Total phosphate phosphorus at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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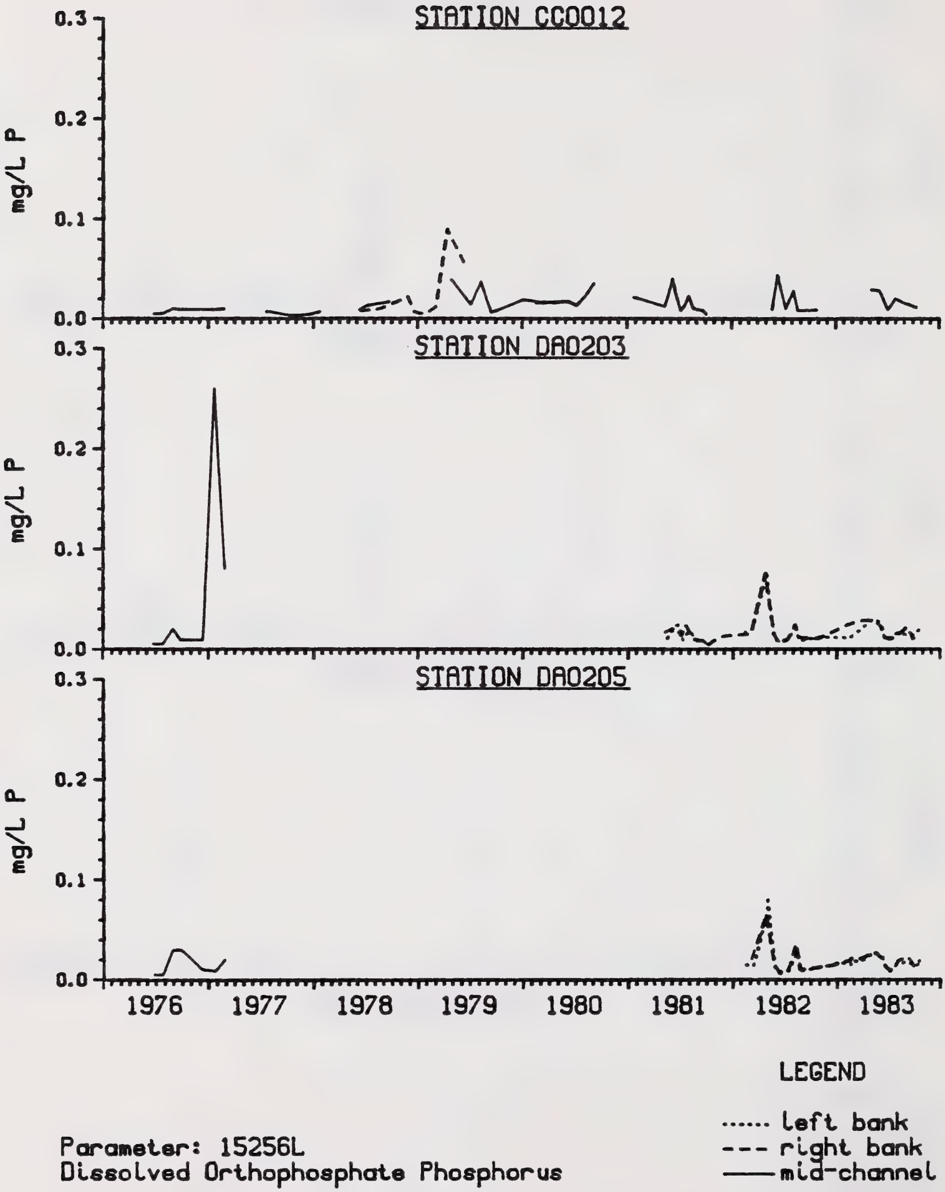
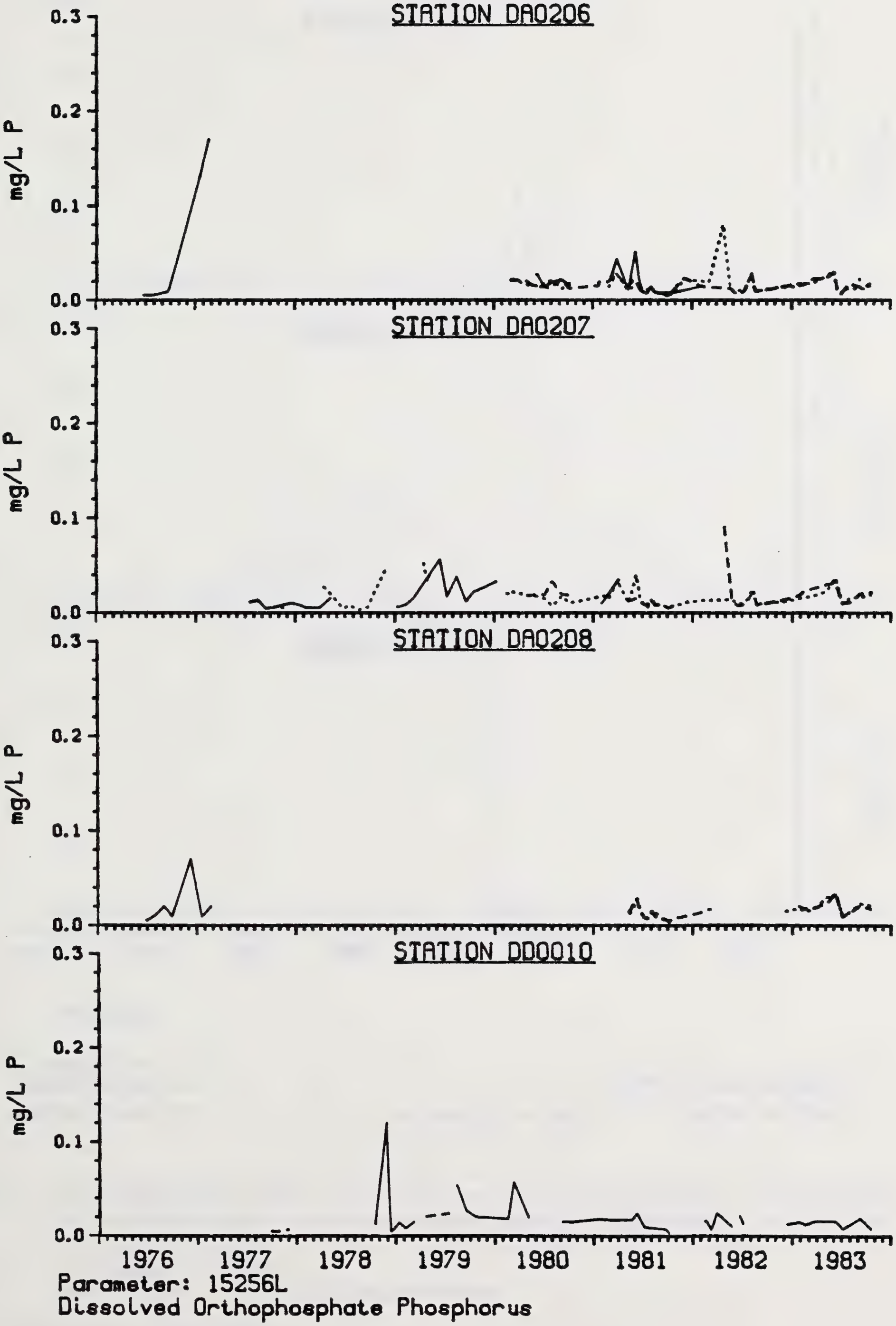


Figure 55. Orthophosphate phosphorus at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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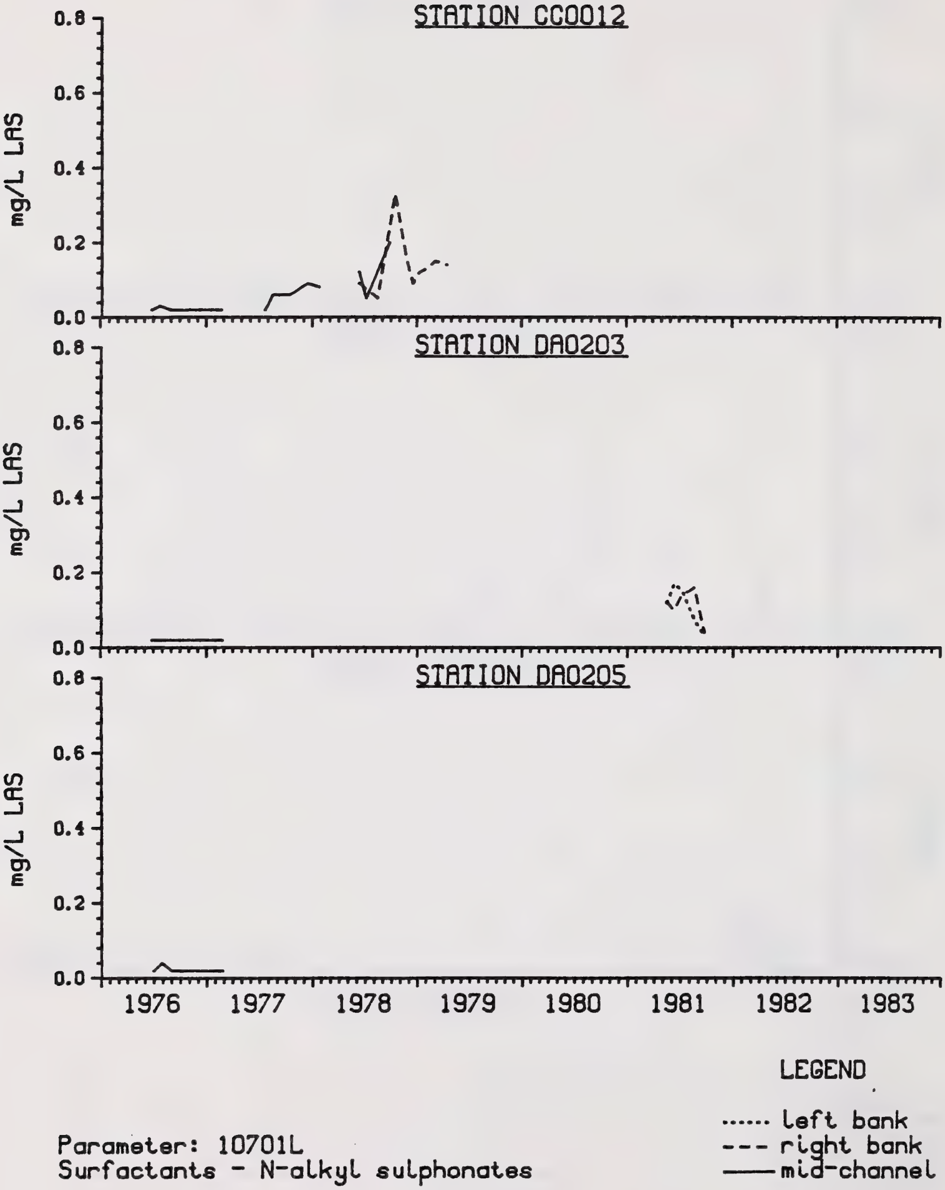
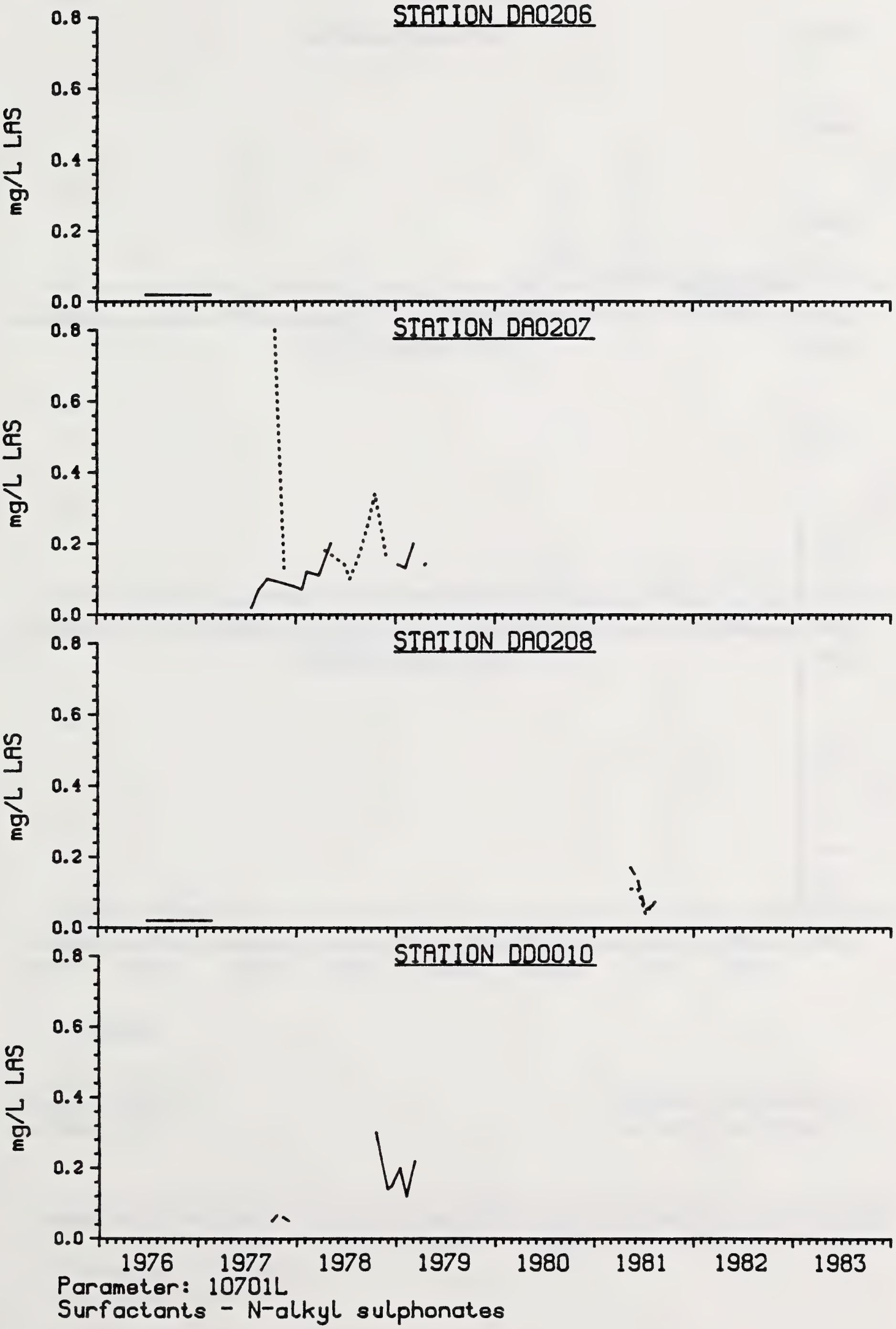


Figure 56. Surfactants at seven stations on the Athabasca River from from 1976 to 1983.

continued . . .



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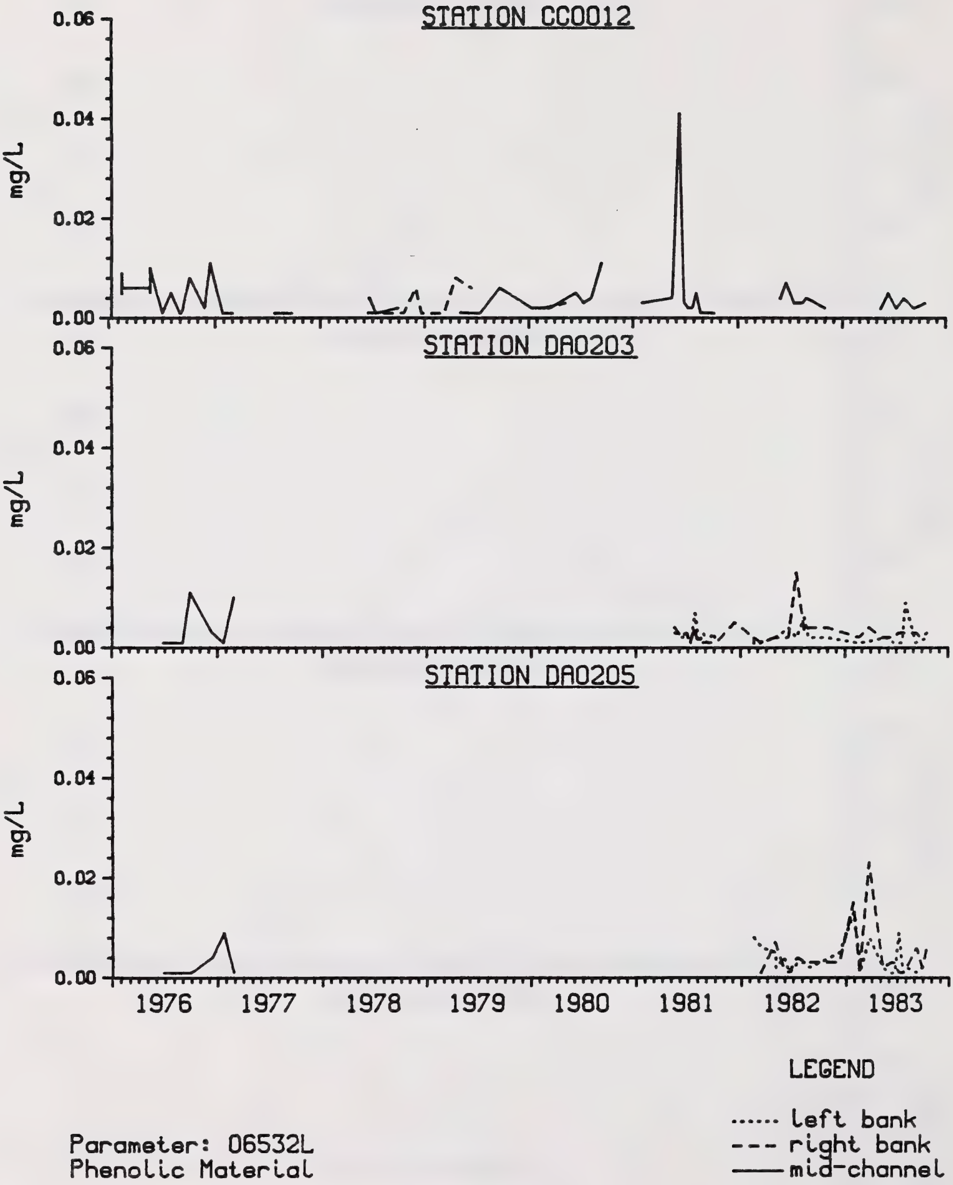
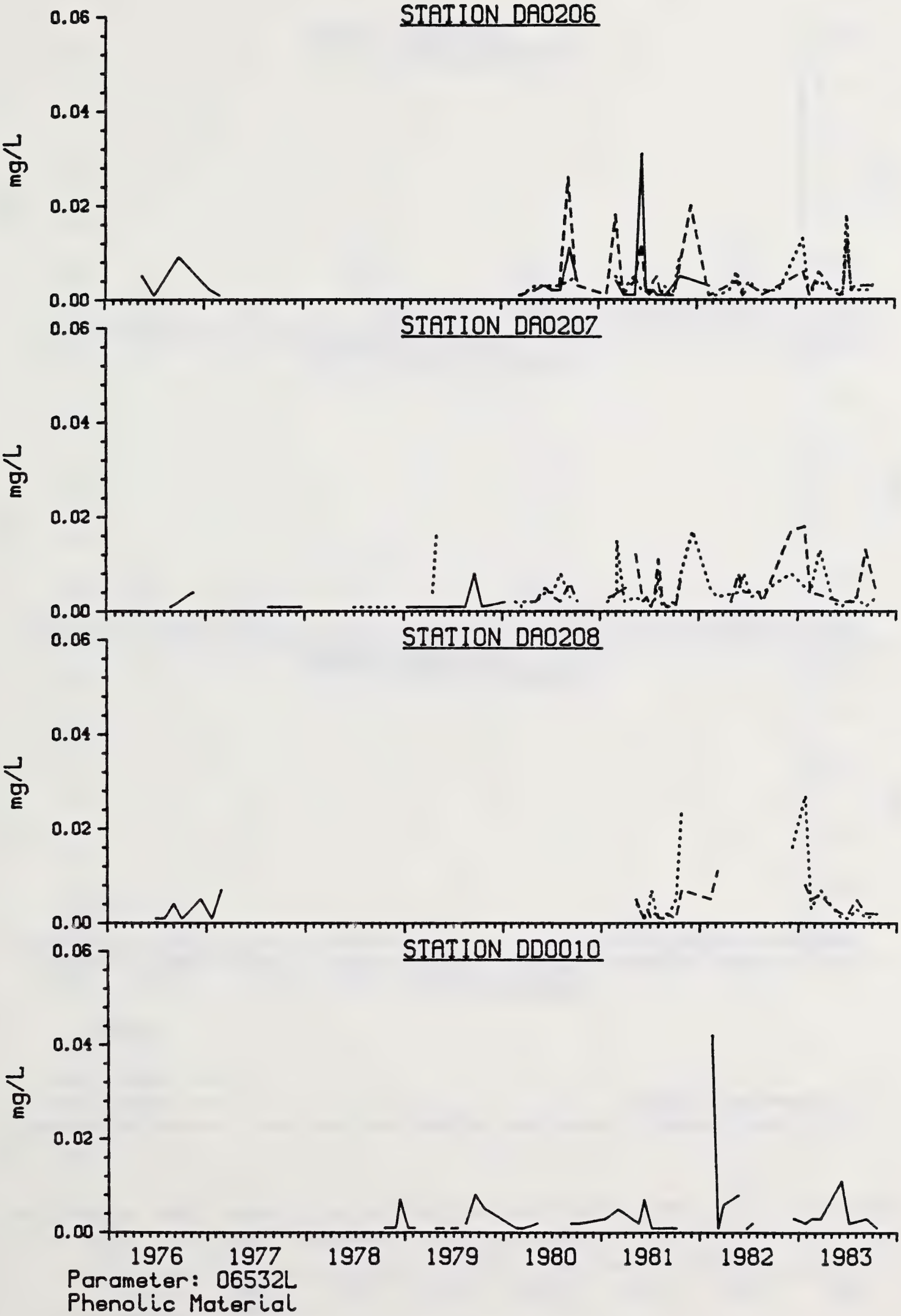


Figure 57. Phenolic material at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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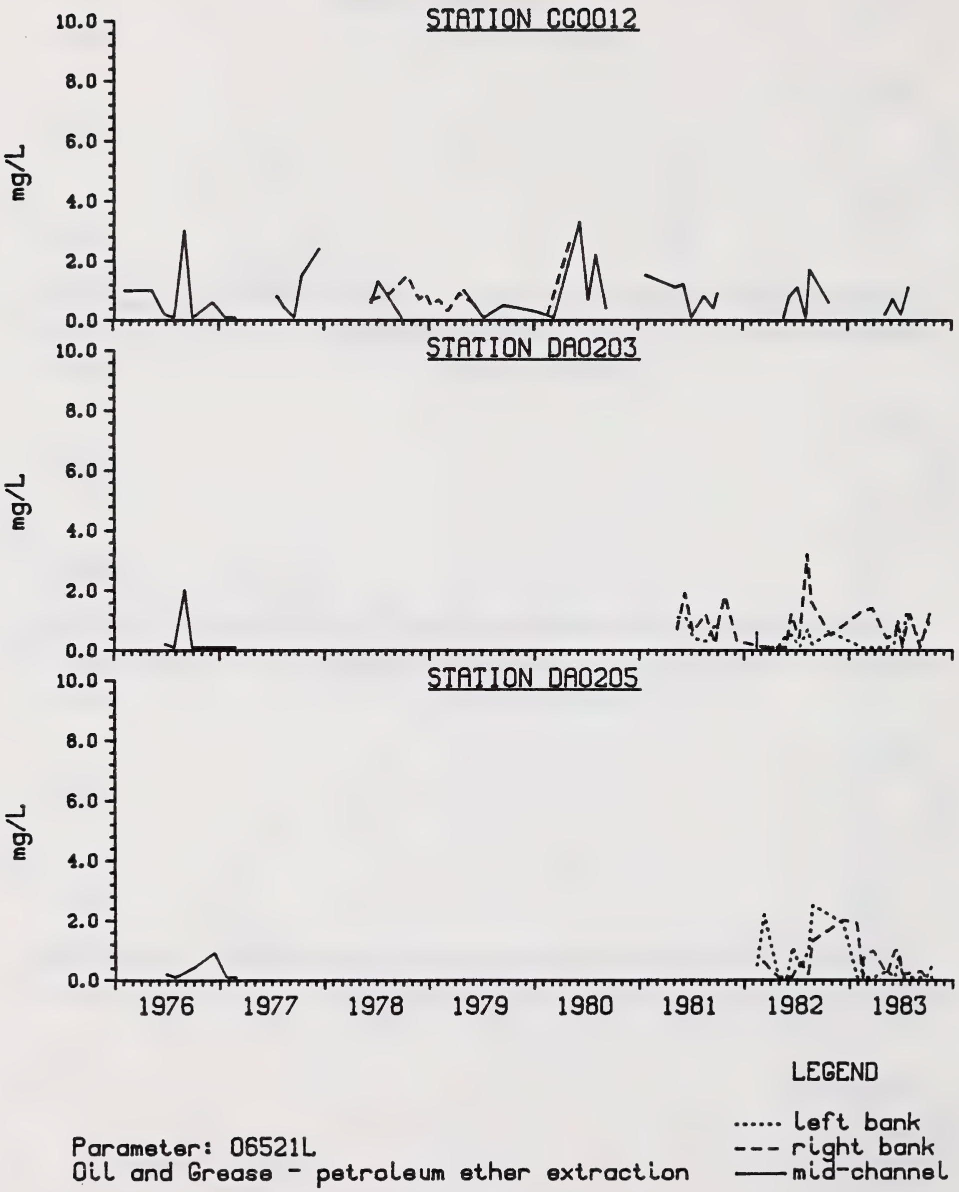


Figure 58. Oil and grease (determined by petroleum ether extraction) at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

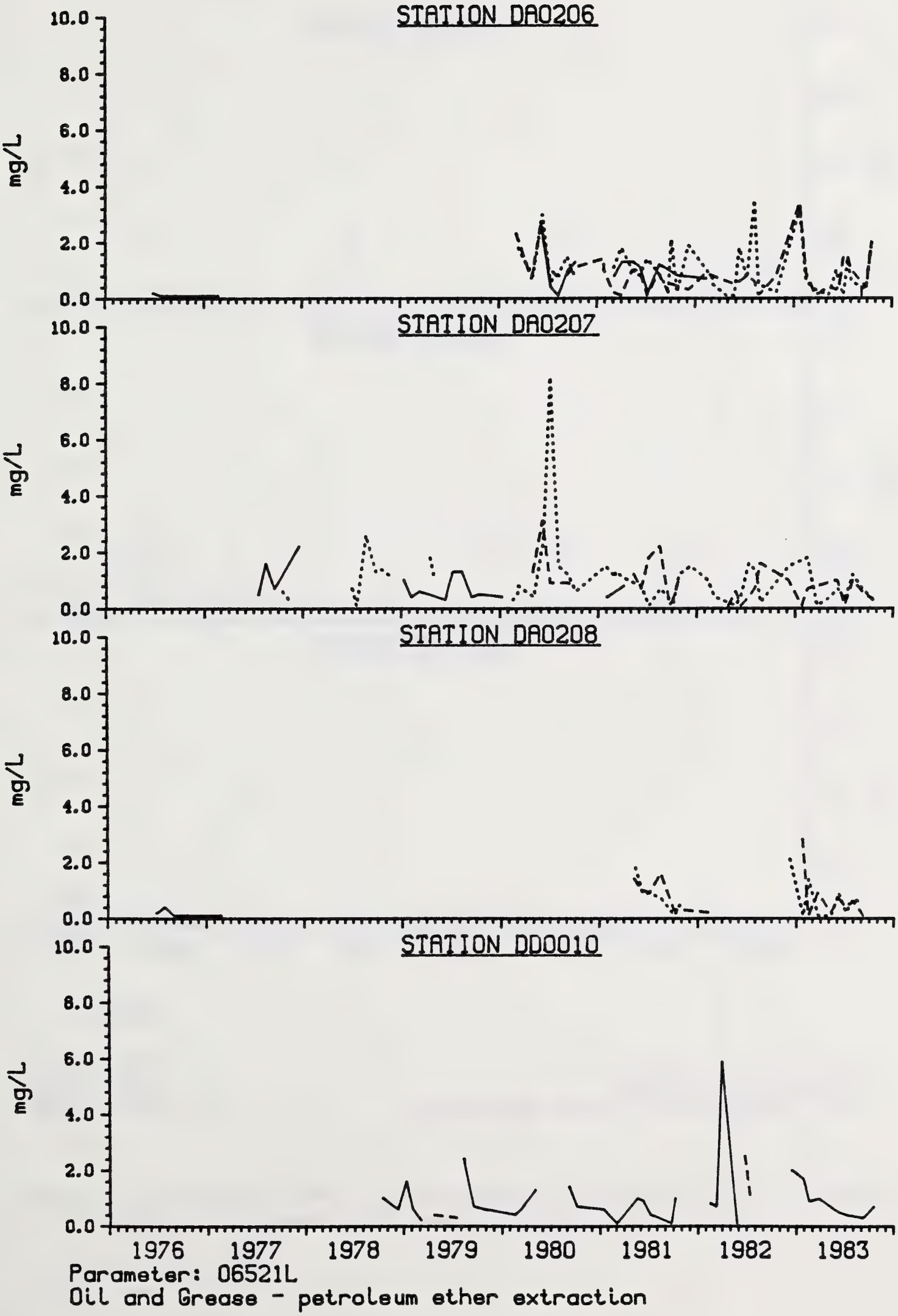


Figure 58. Concluded.

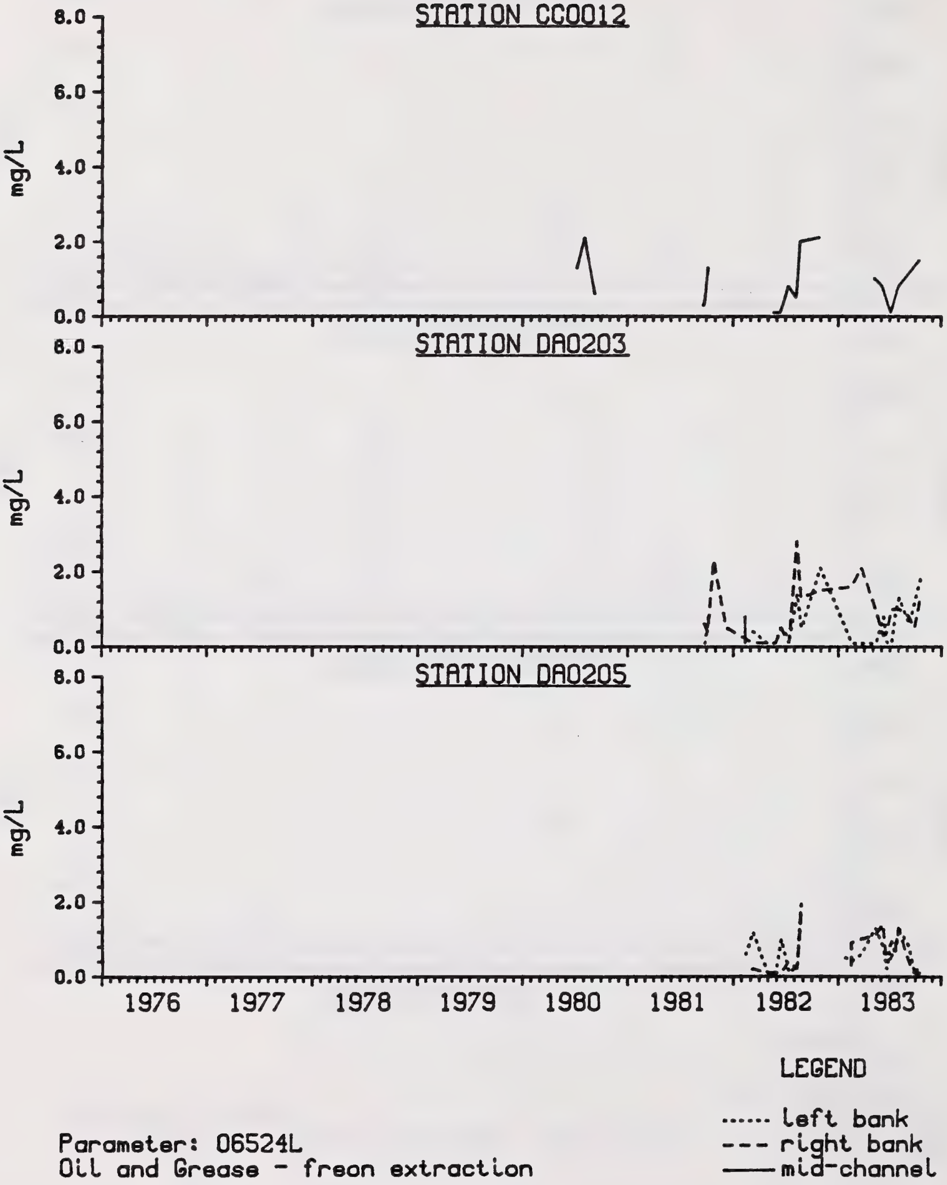
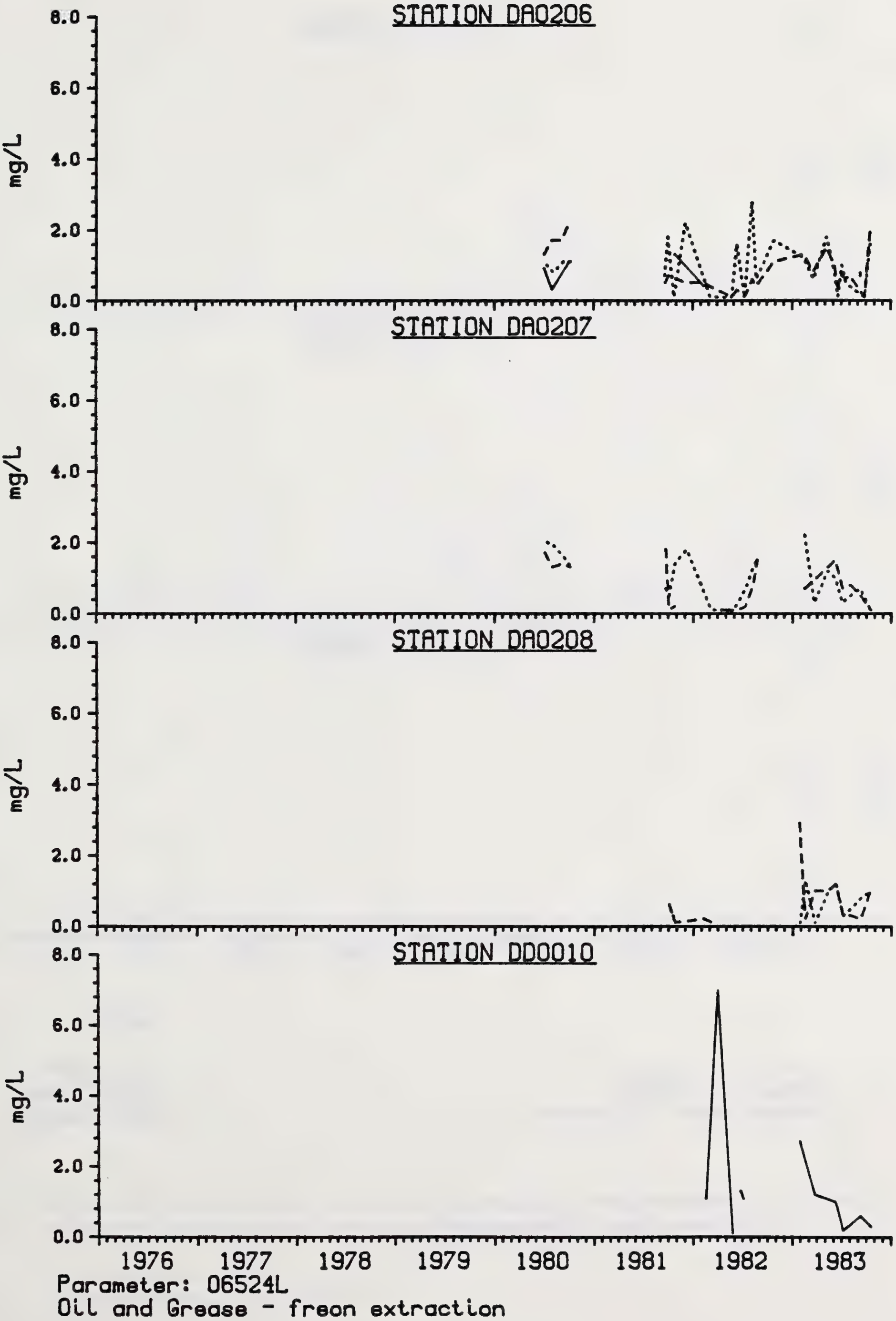


Figure 59. Oil and grease (determined by freon extraction) at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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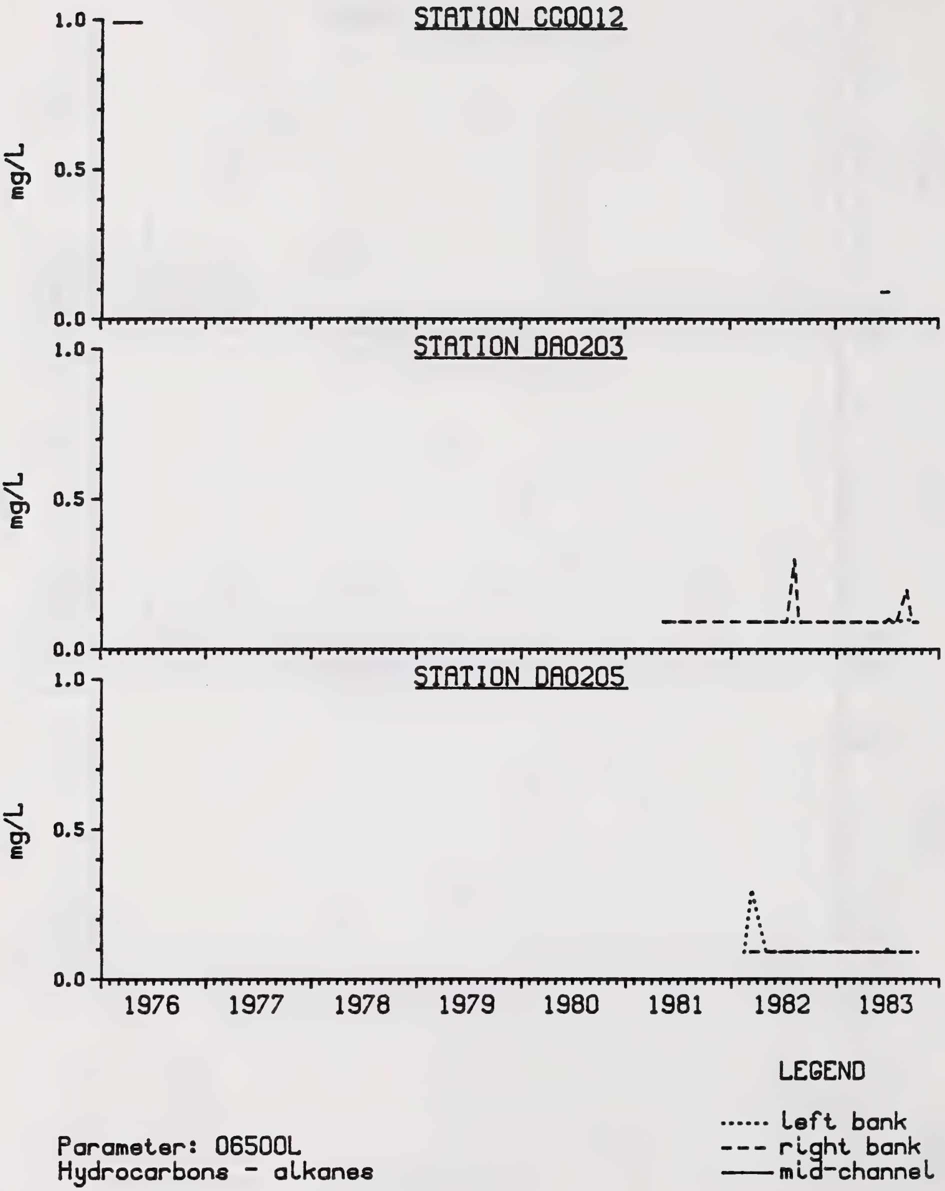


Figure 60. Hydrocarbons (alkanes) at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

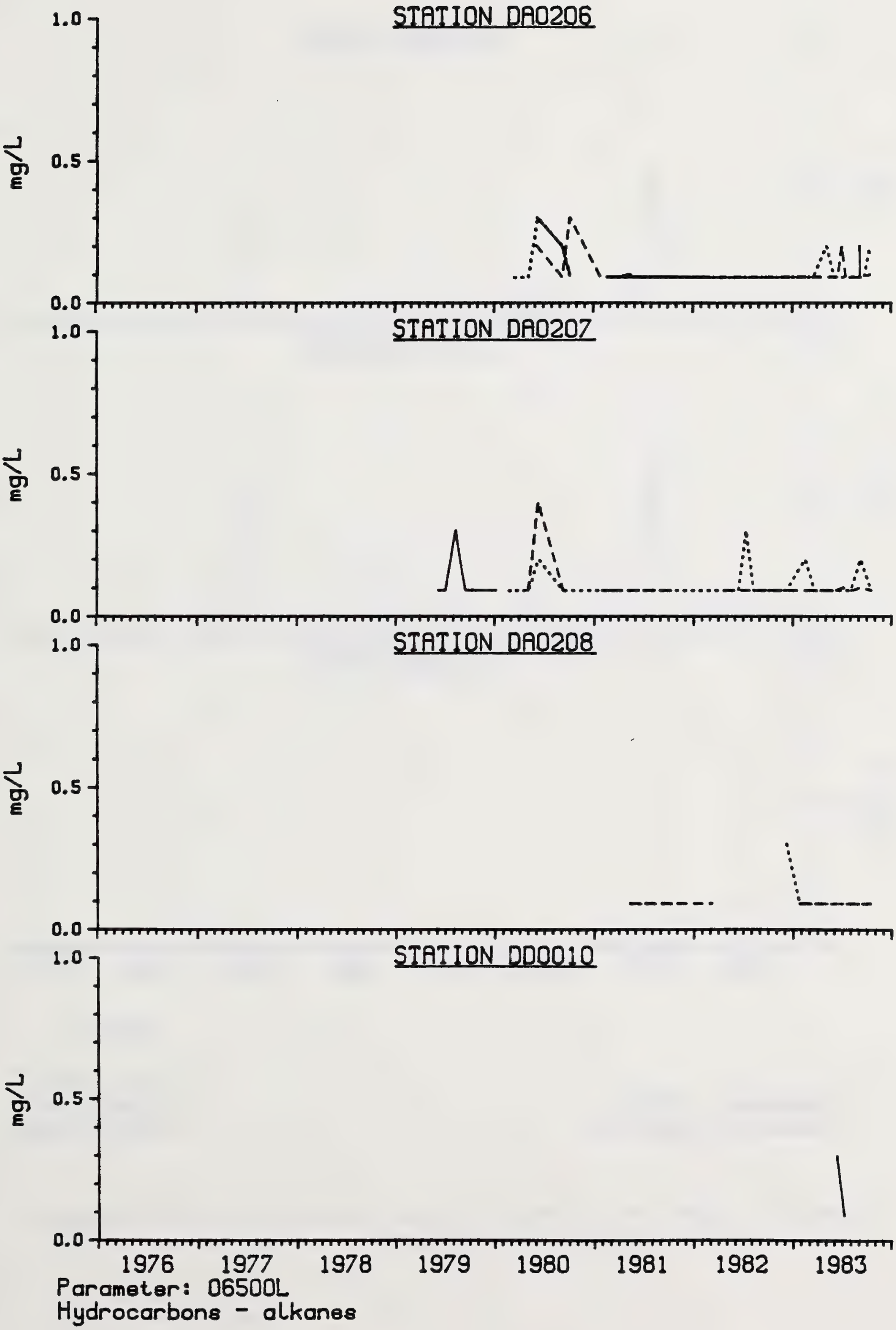


Figure 60. Concluded.

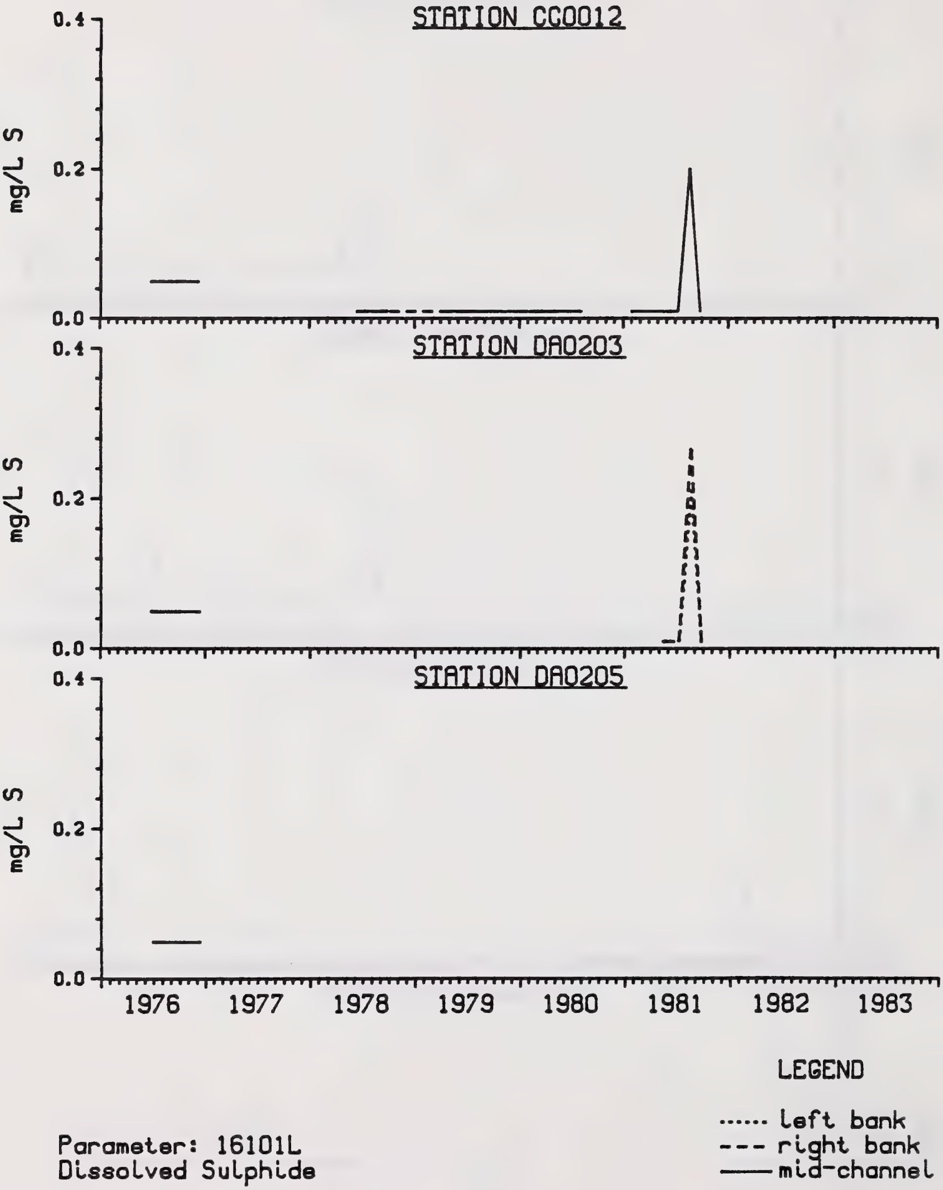
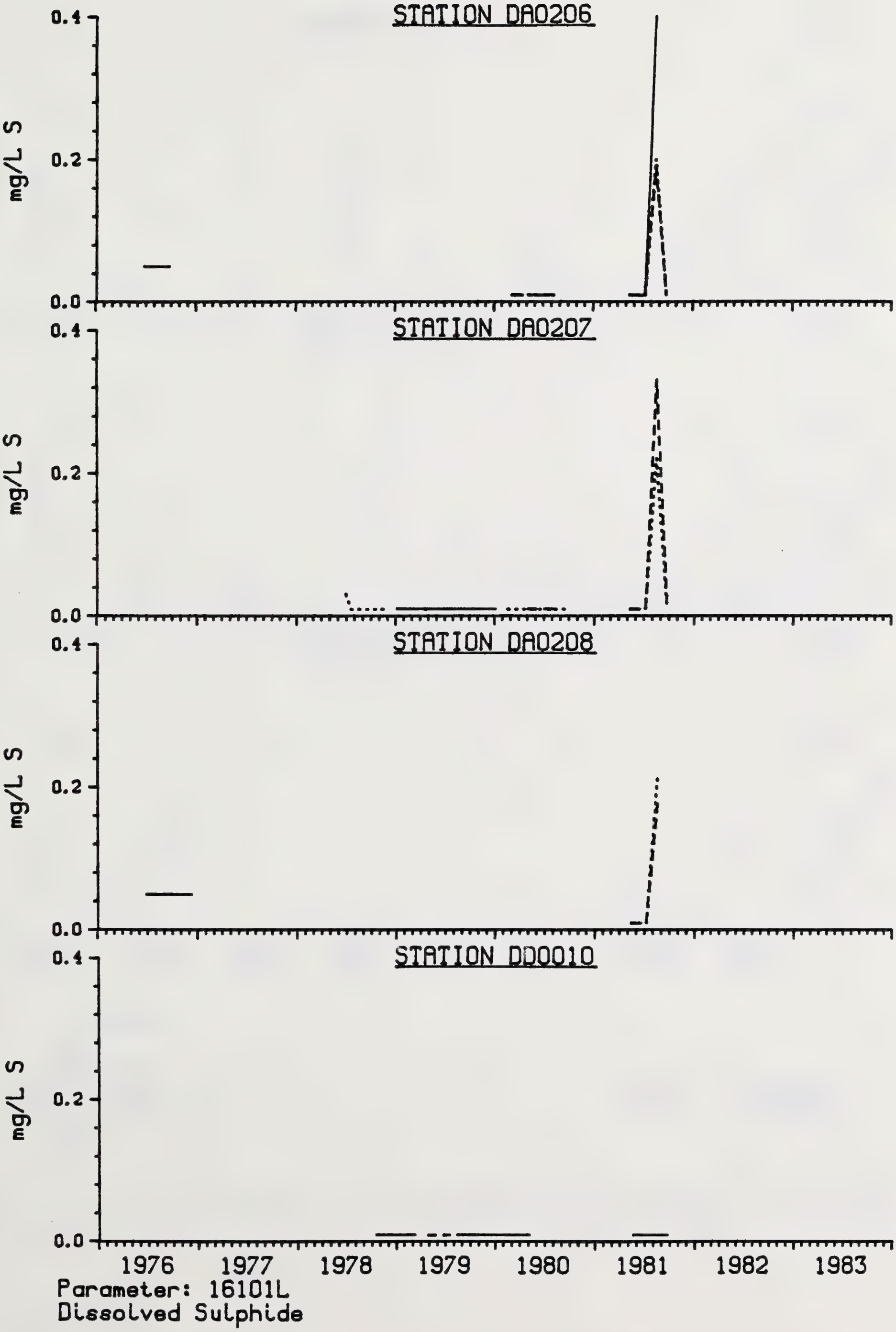


Figure 61. Dissolved sulphide at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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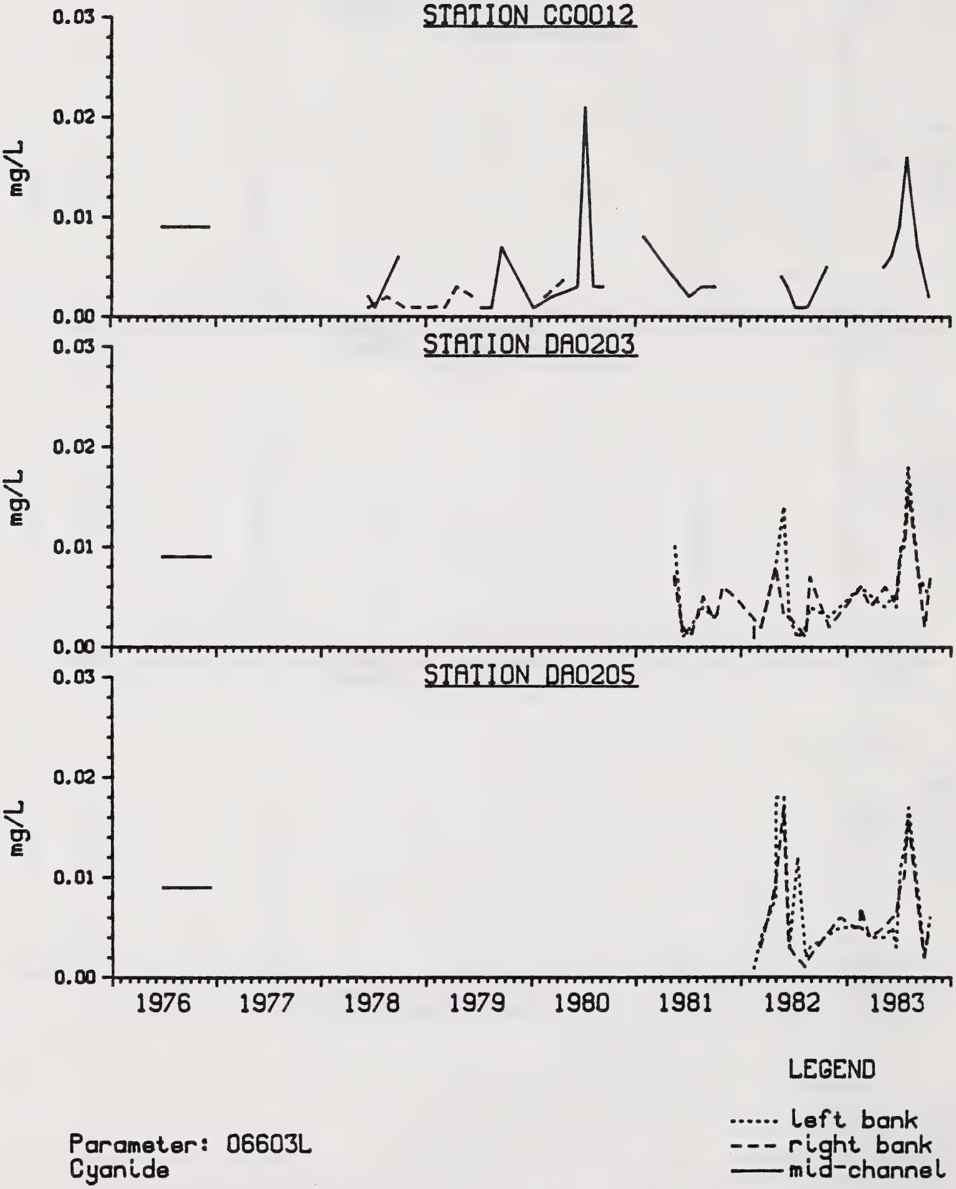
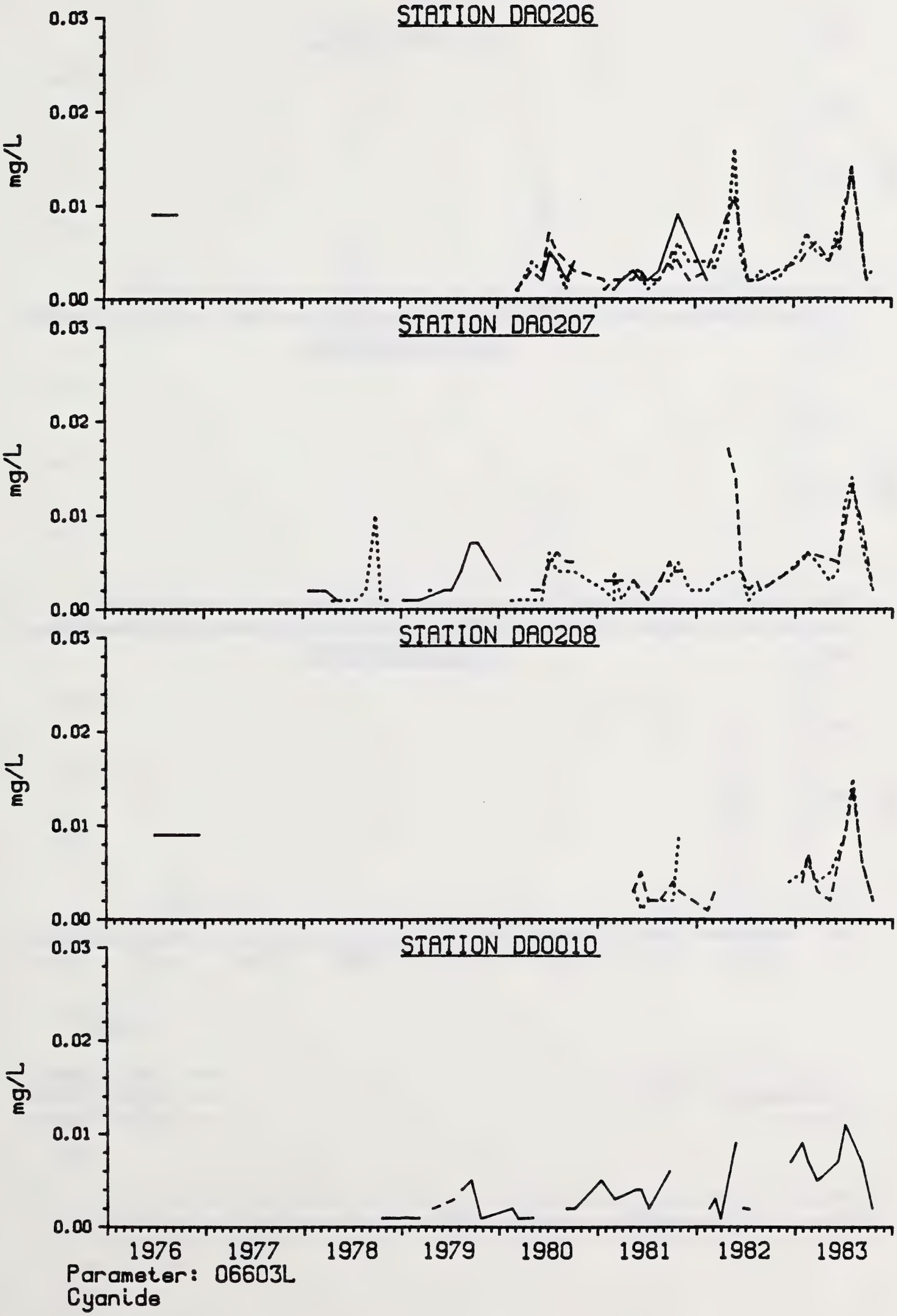


Figure 62. Cyanide at seven stations on the Athabasca River from 1976 to 1983.

continued . . .



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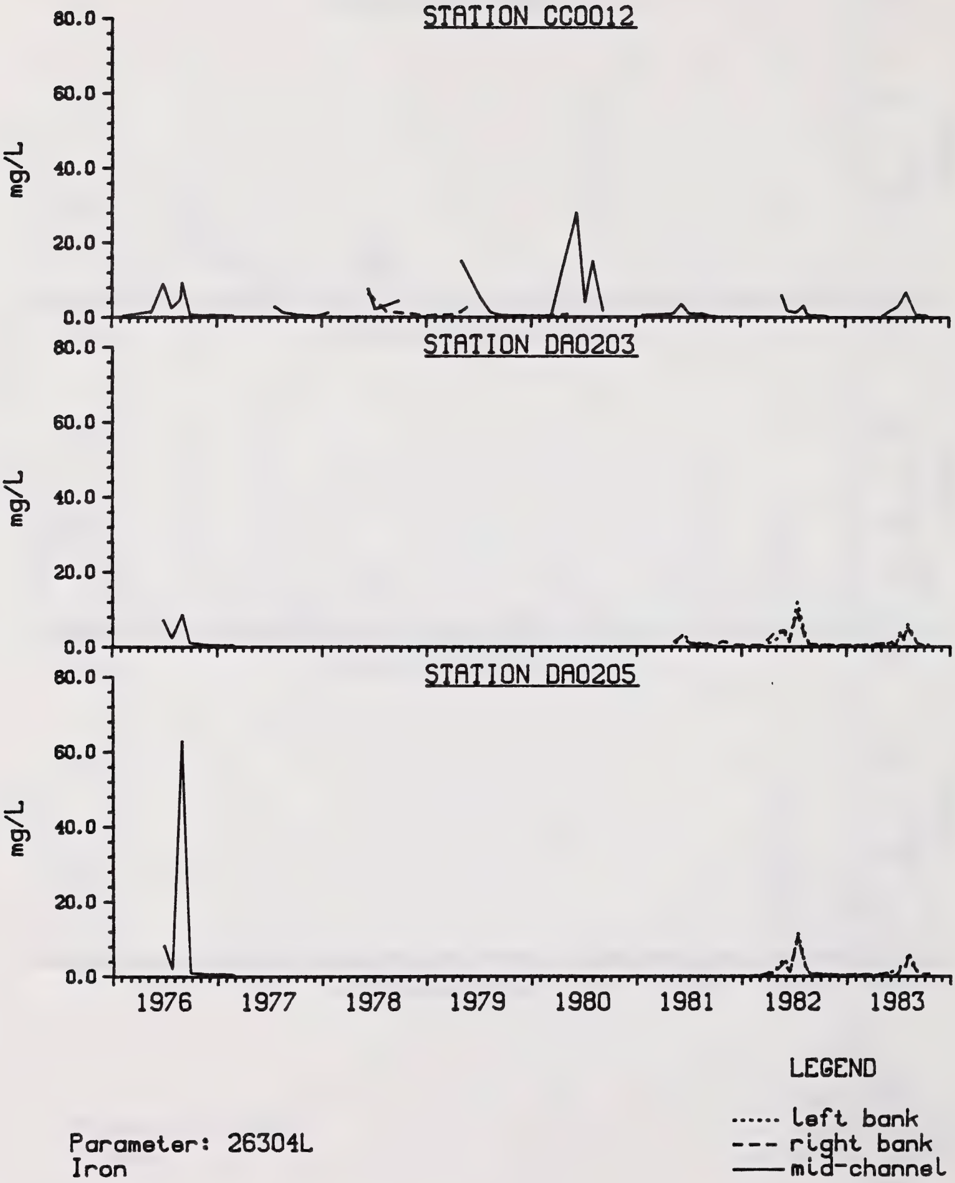


Figure 63. Iron at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

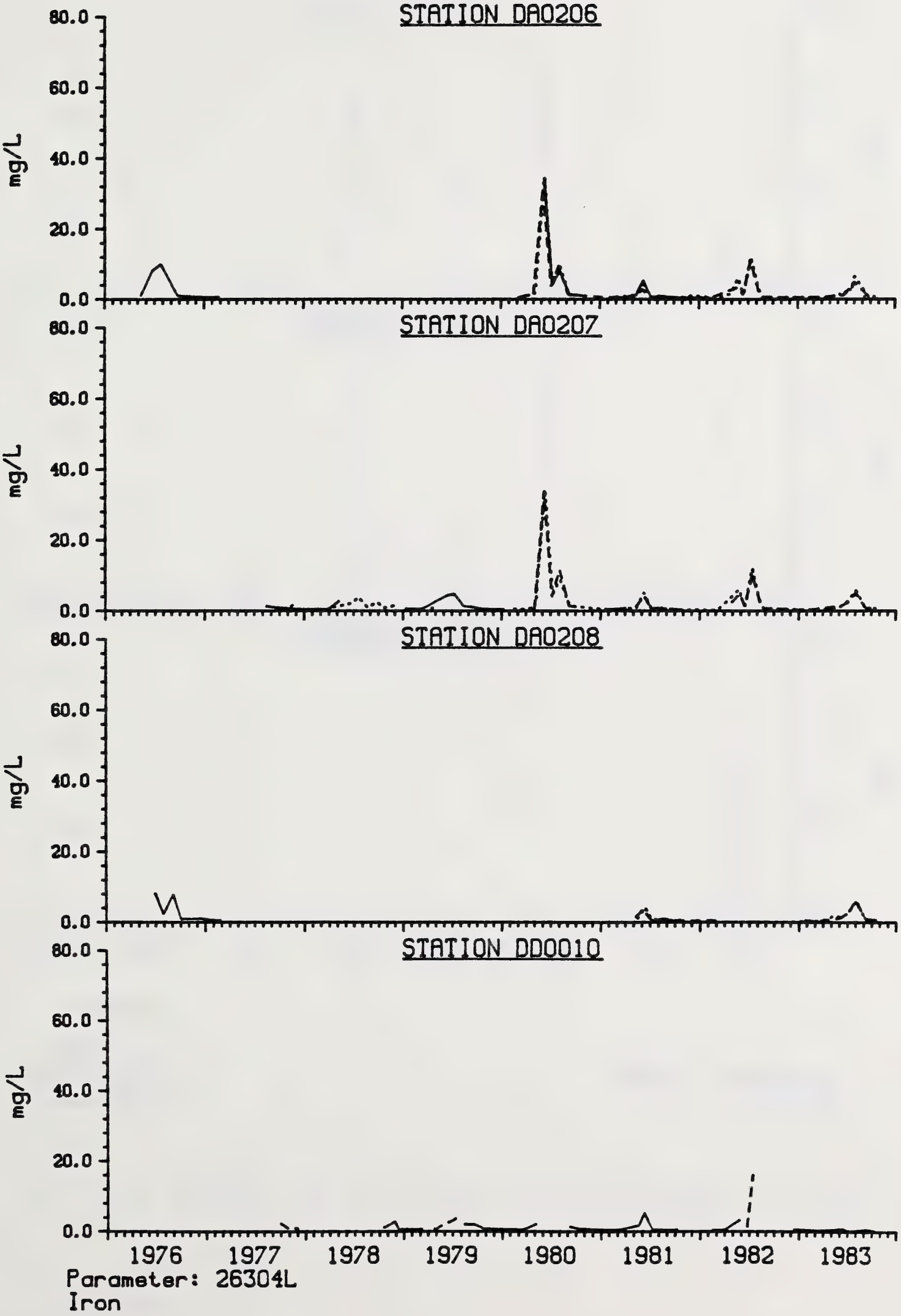


Figure 63. Concluded.

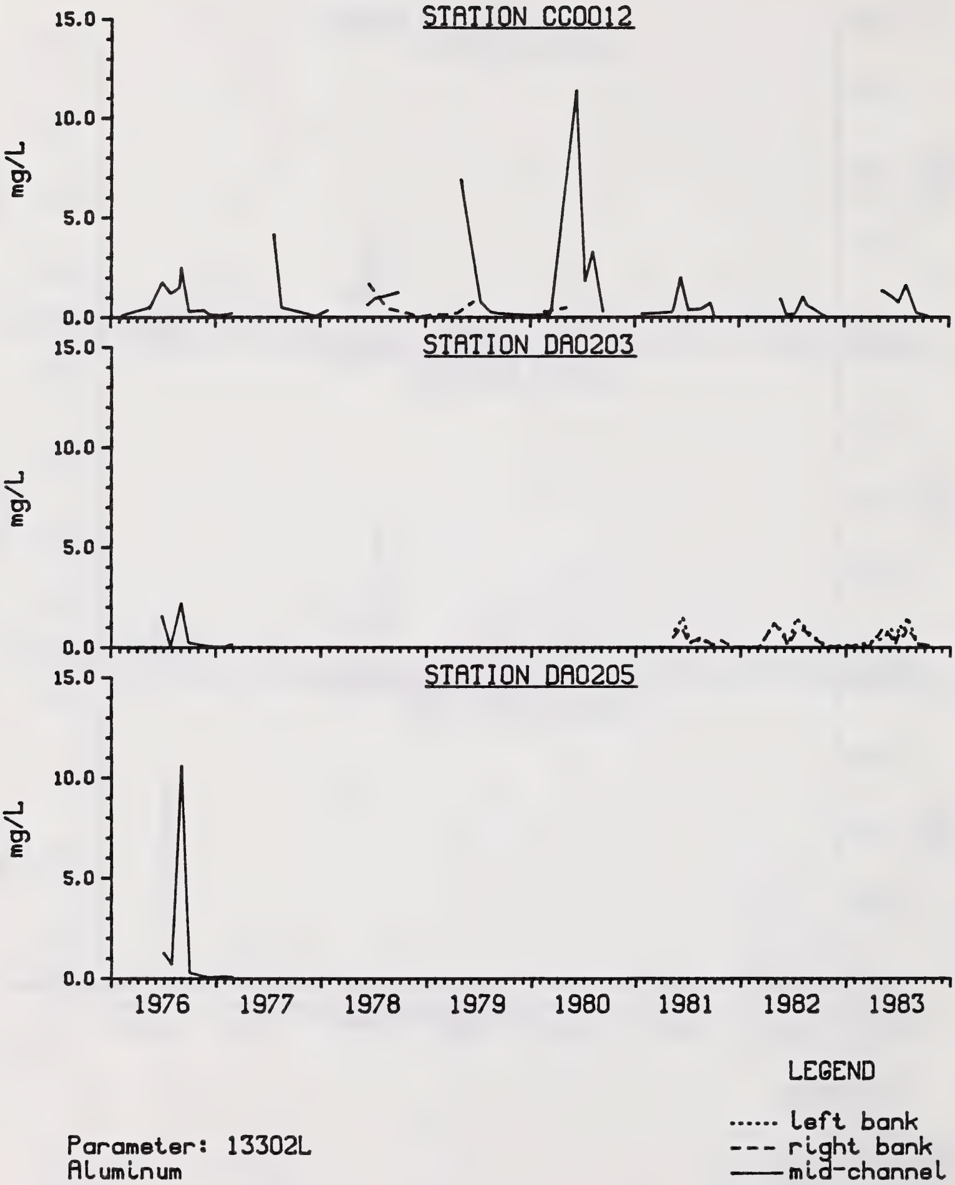


Figure 64. Aluminum at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

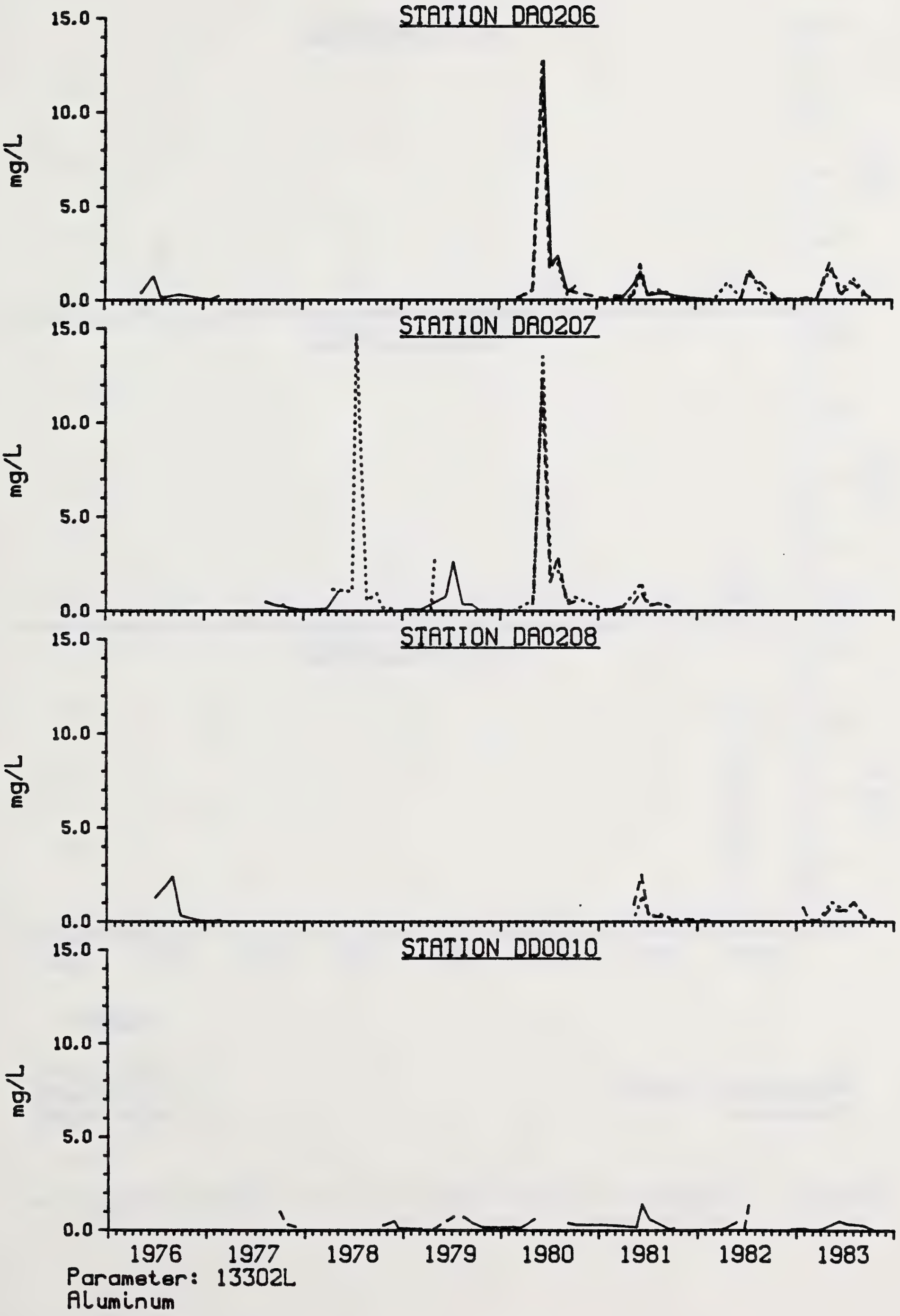


Figure 64. Concluded.

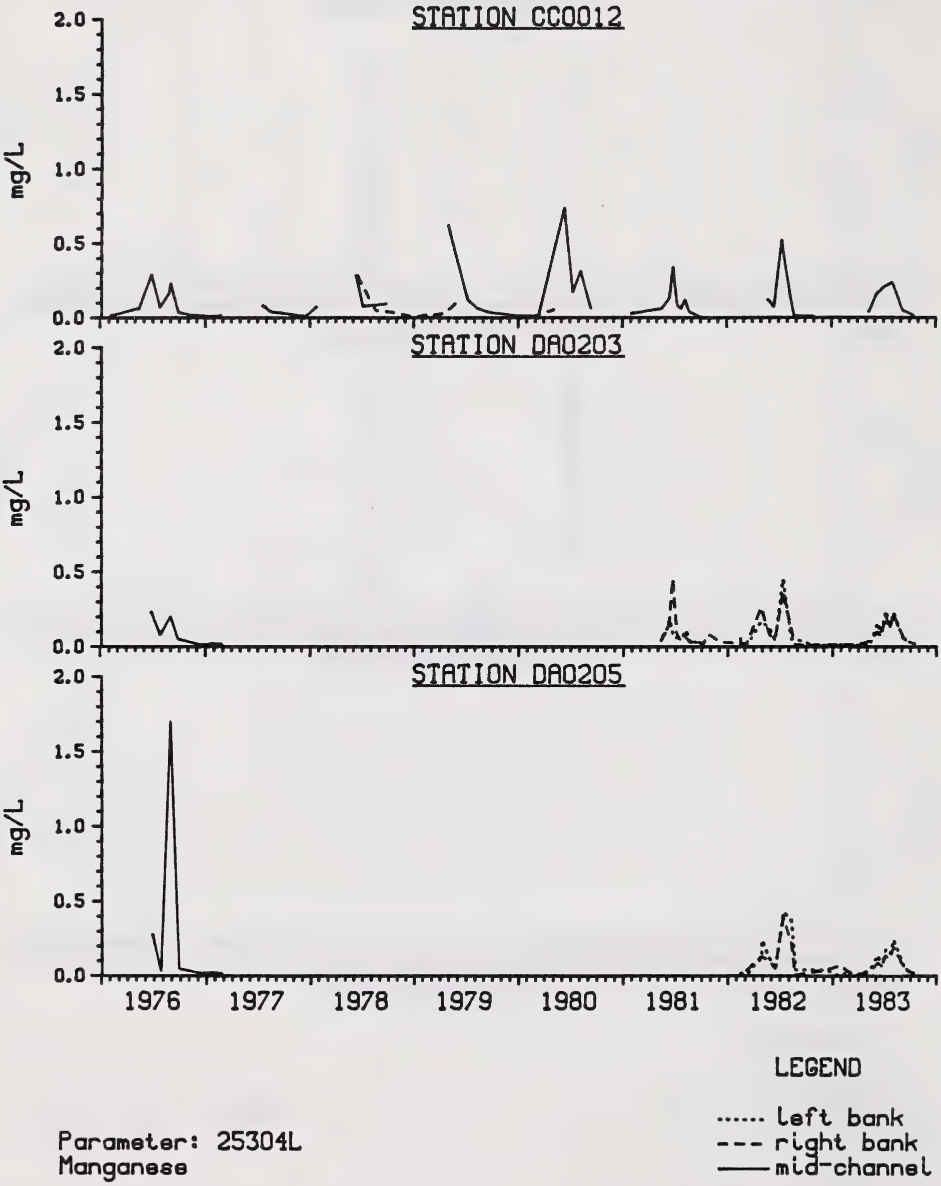


Figure 65. Manganese at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

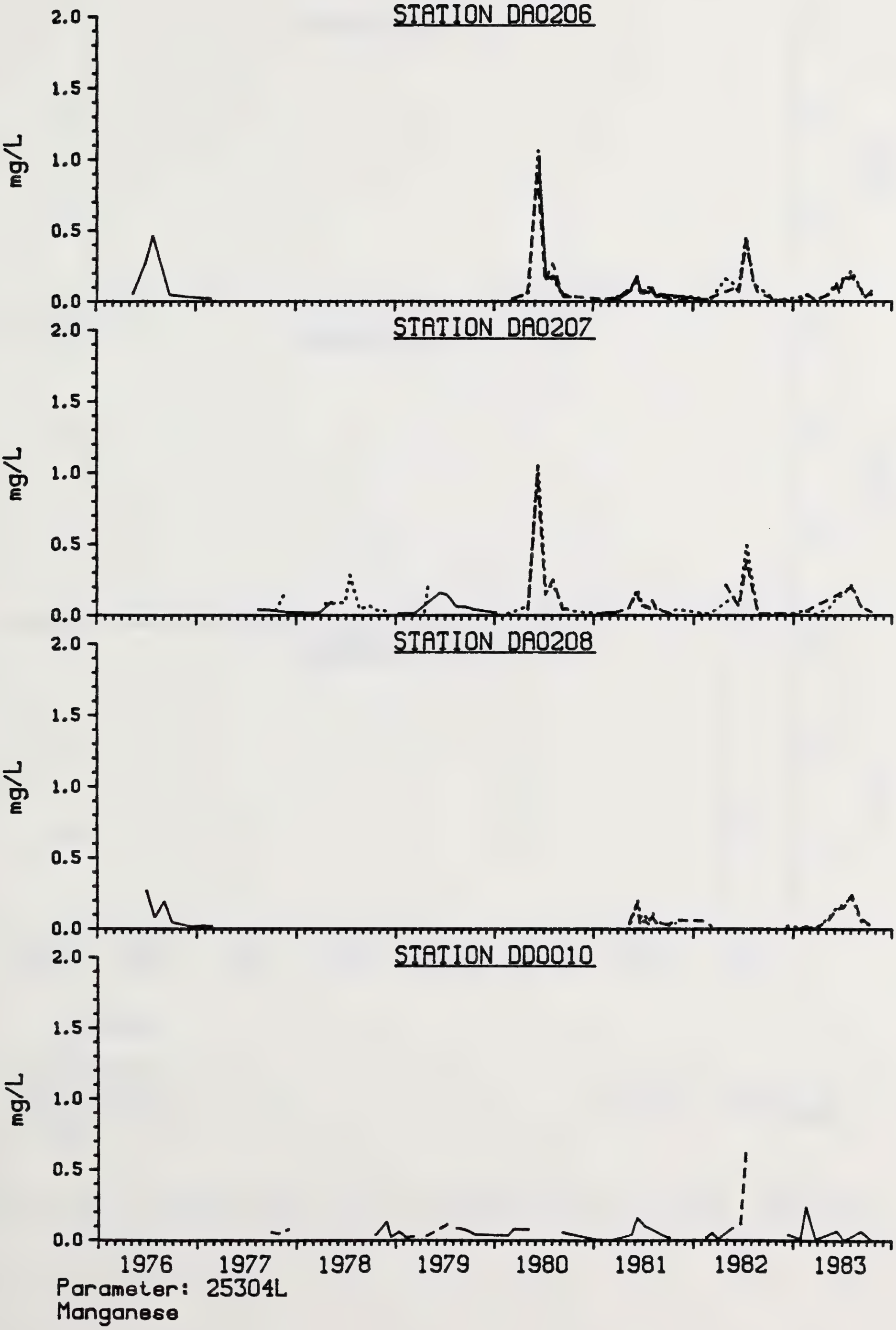


Figure 65. Concluded.

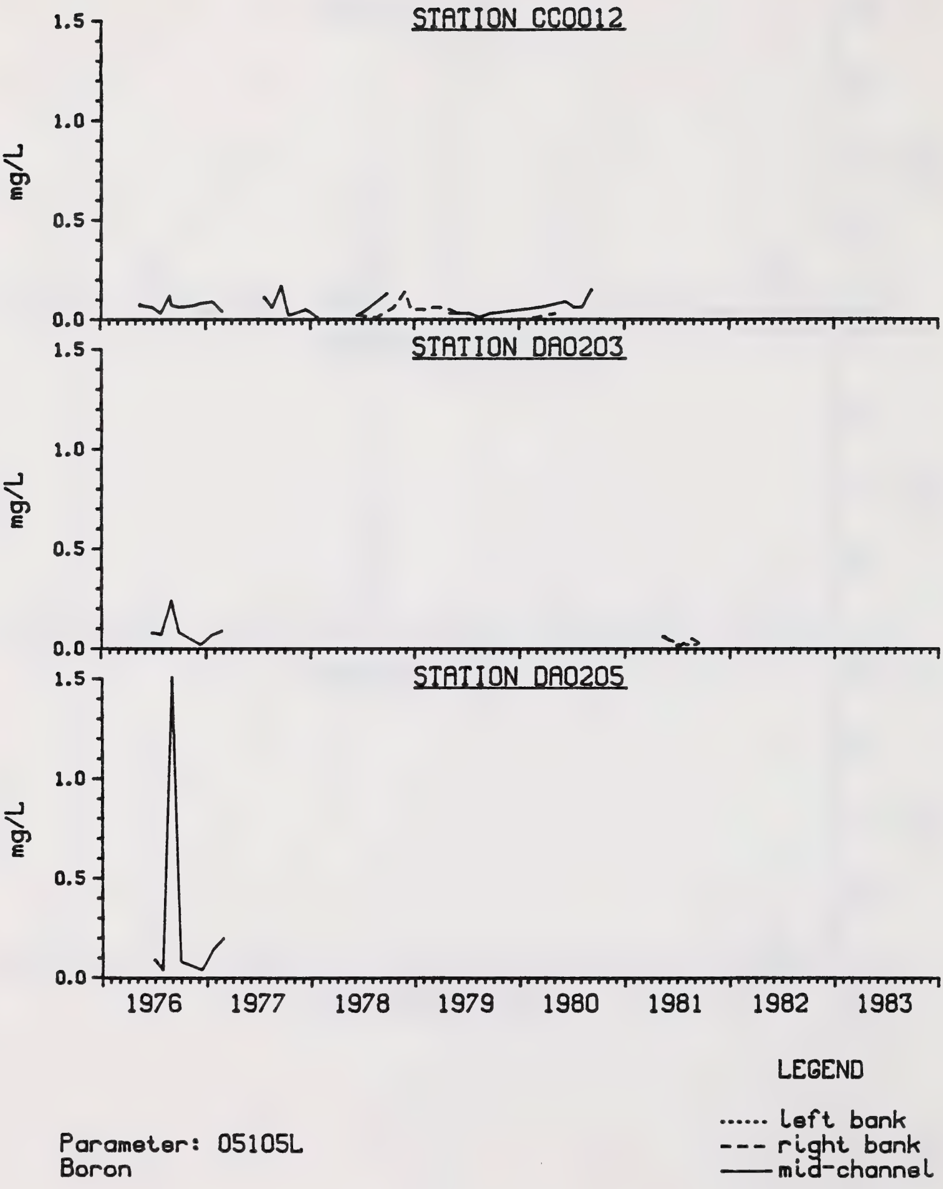


Figure 66. Boron at seven stations on the Athabasca River from 1976 to 1981.

continued . . .

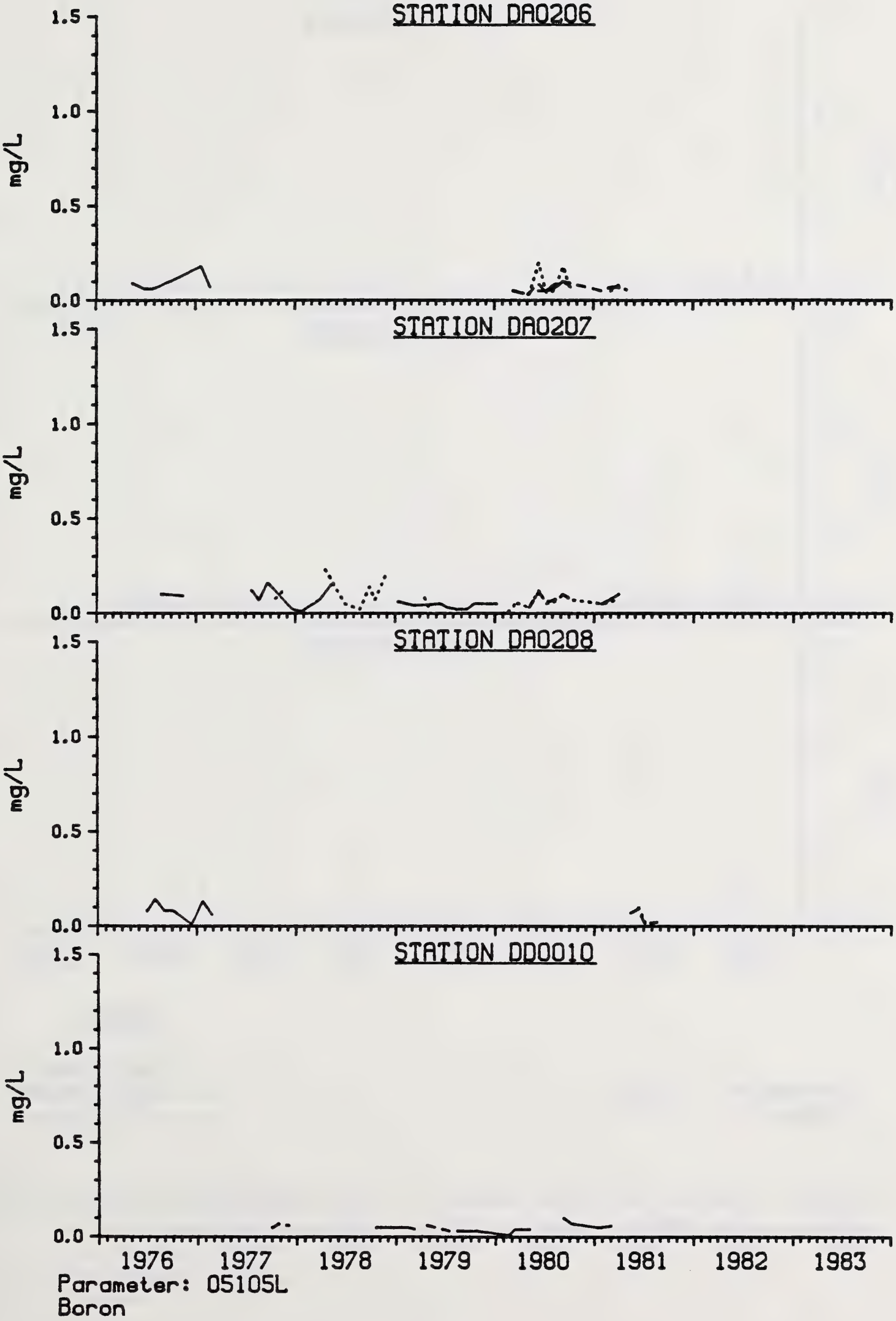


Figure 66. Concluded.

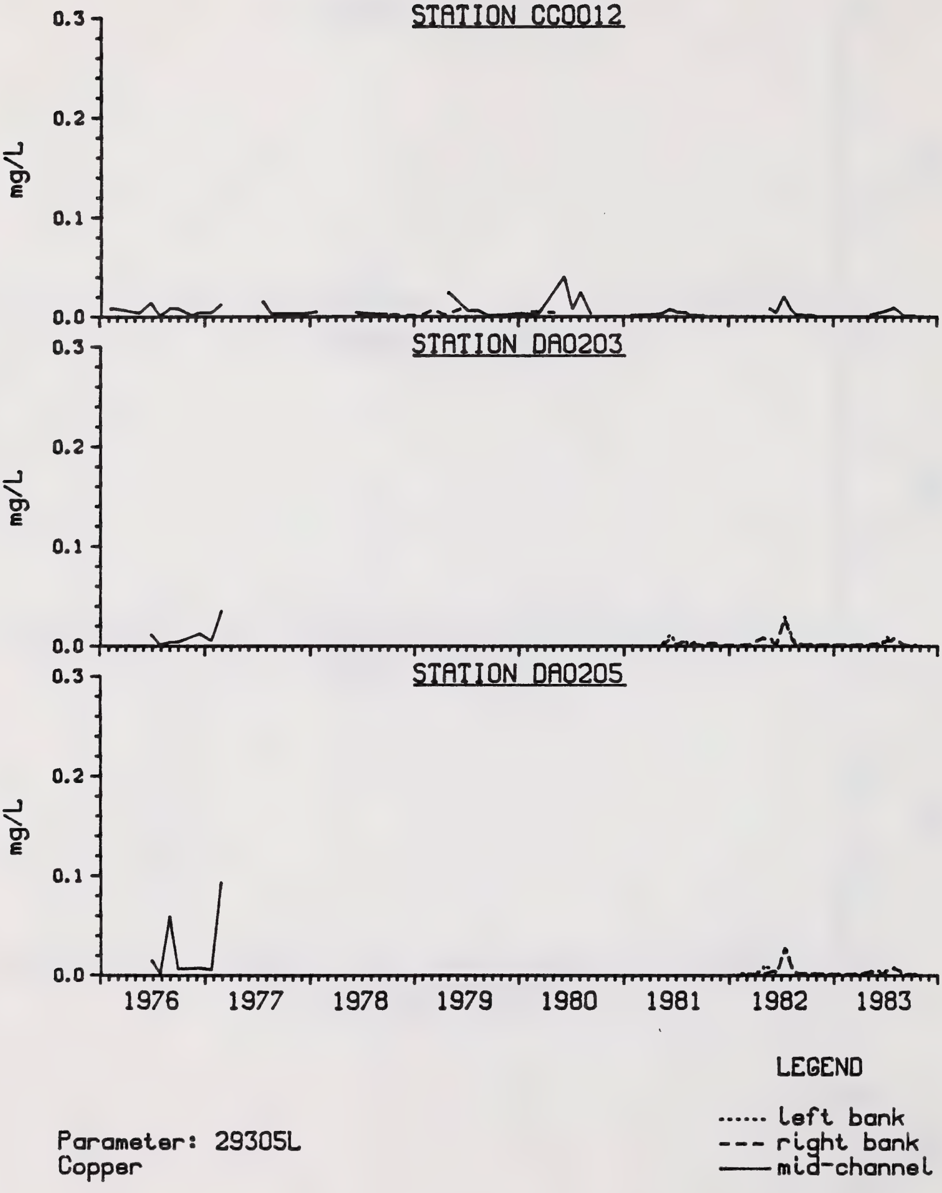


Figure 67. Copper at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

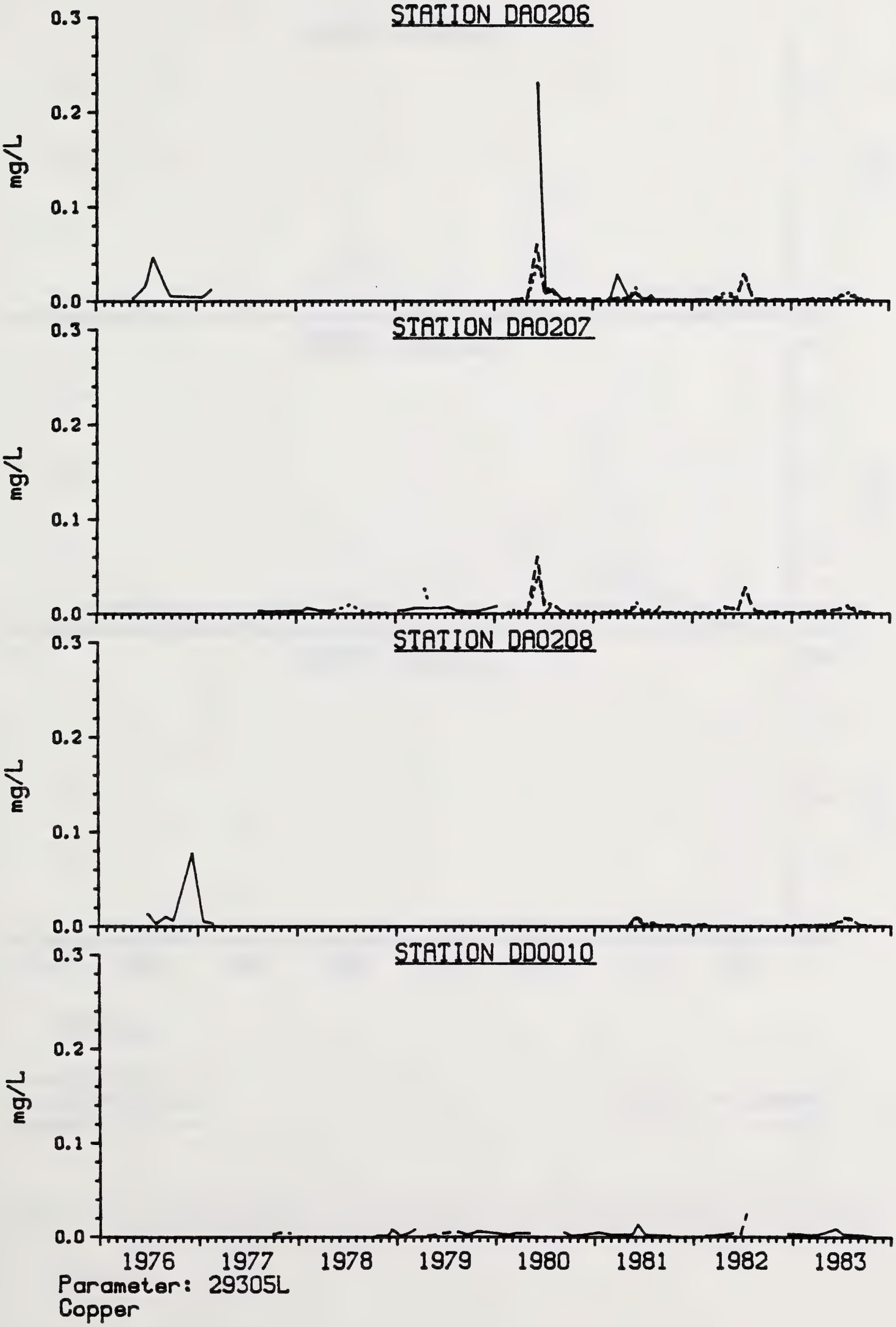


Figure 67. Concluded.

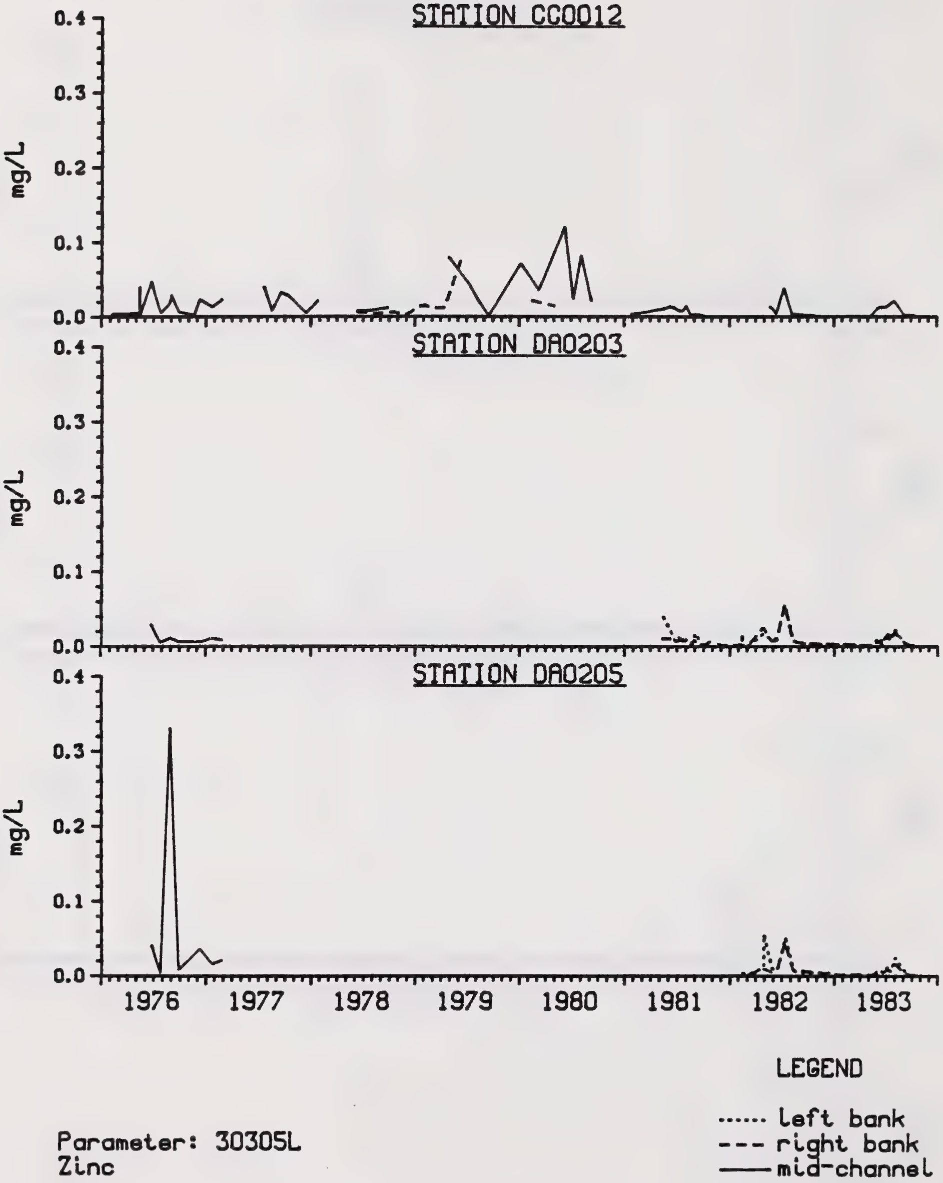


Figure 68. Zinc at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

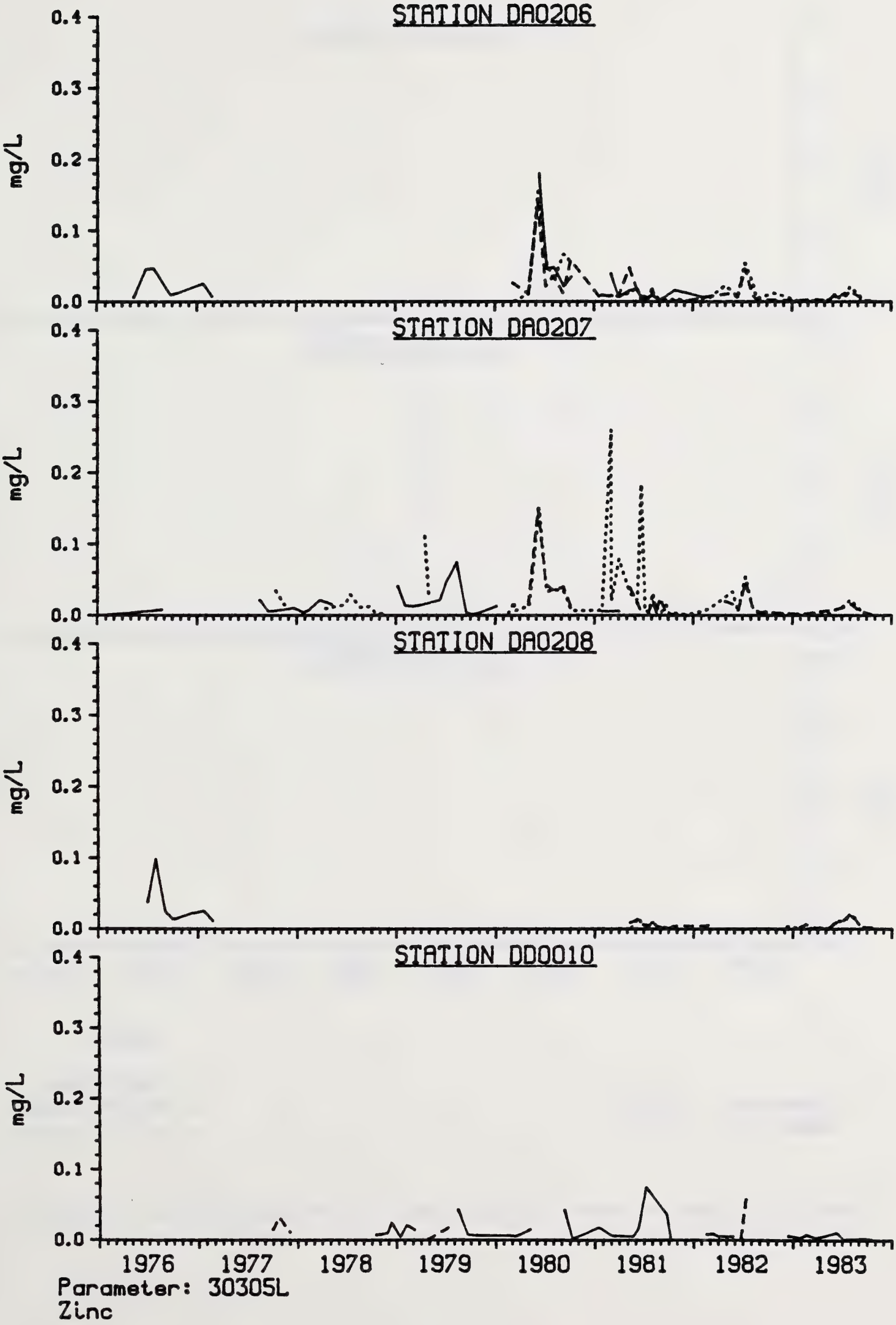


Figure 68. Concluded.

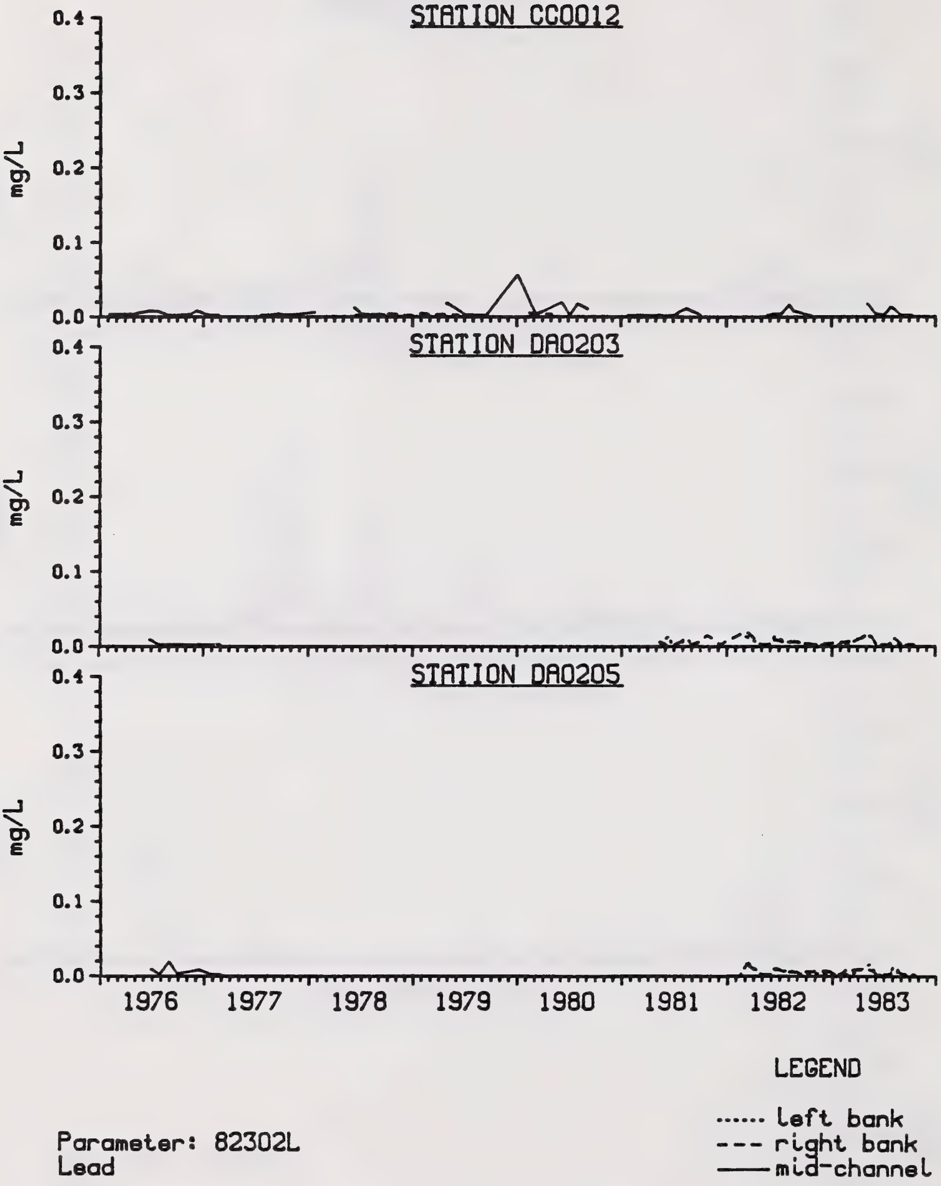


Figure 69. Lead at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

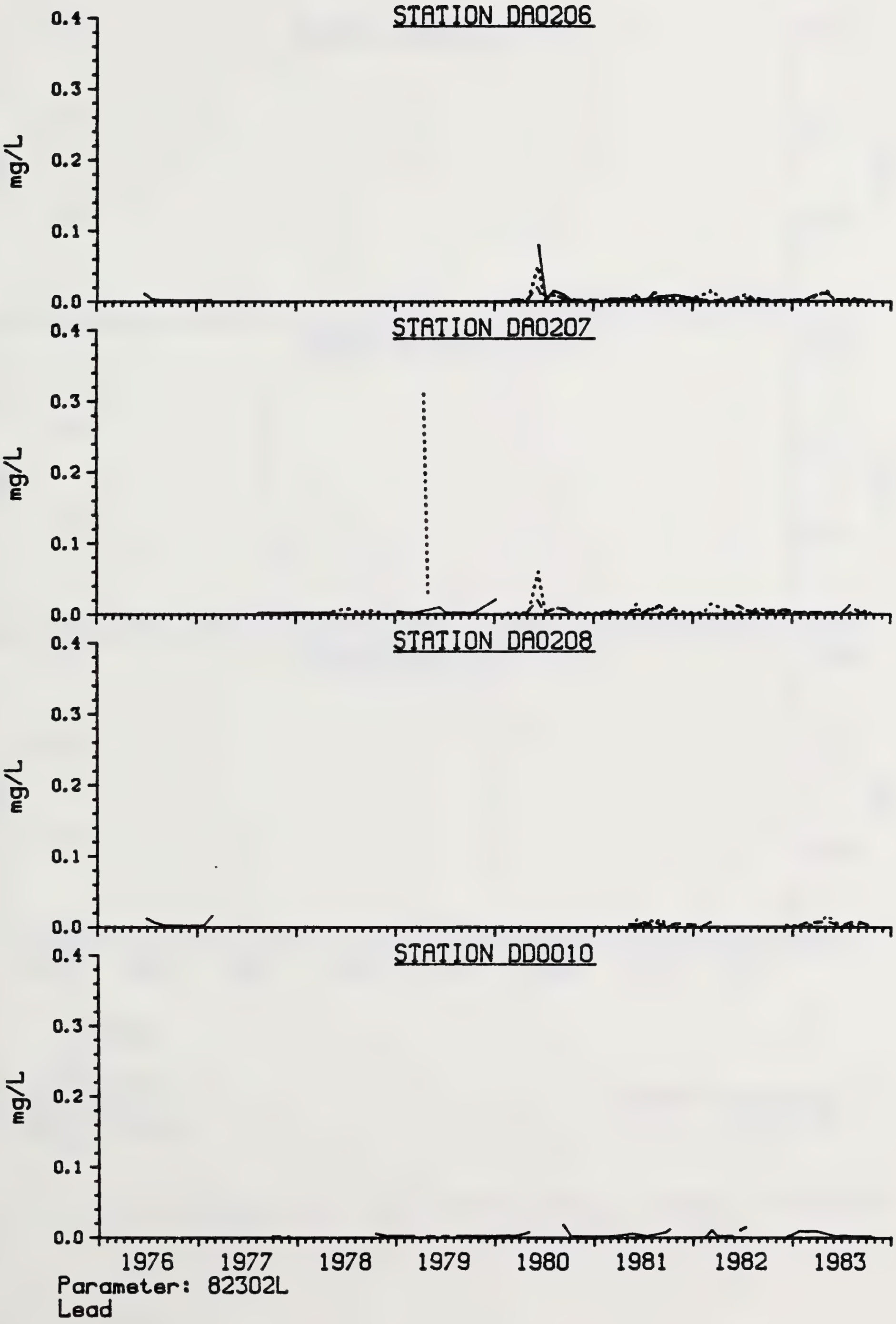


Figure 69. Concluded.

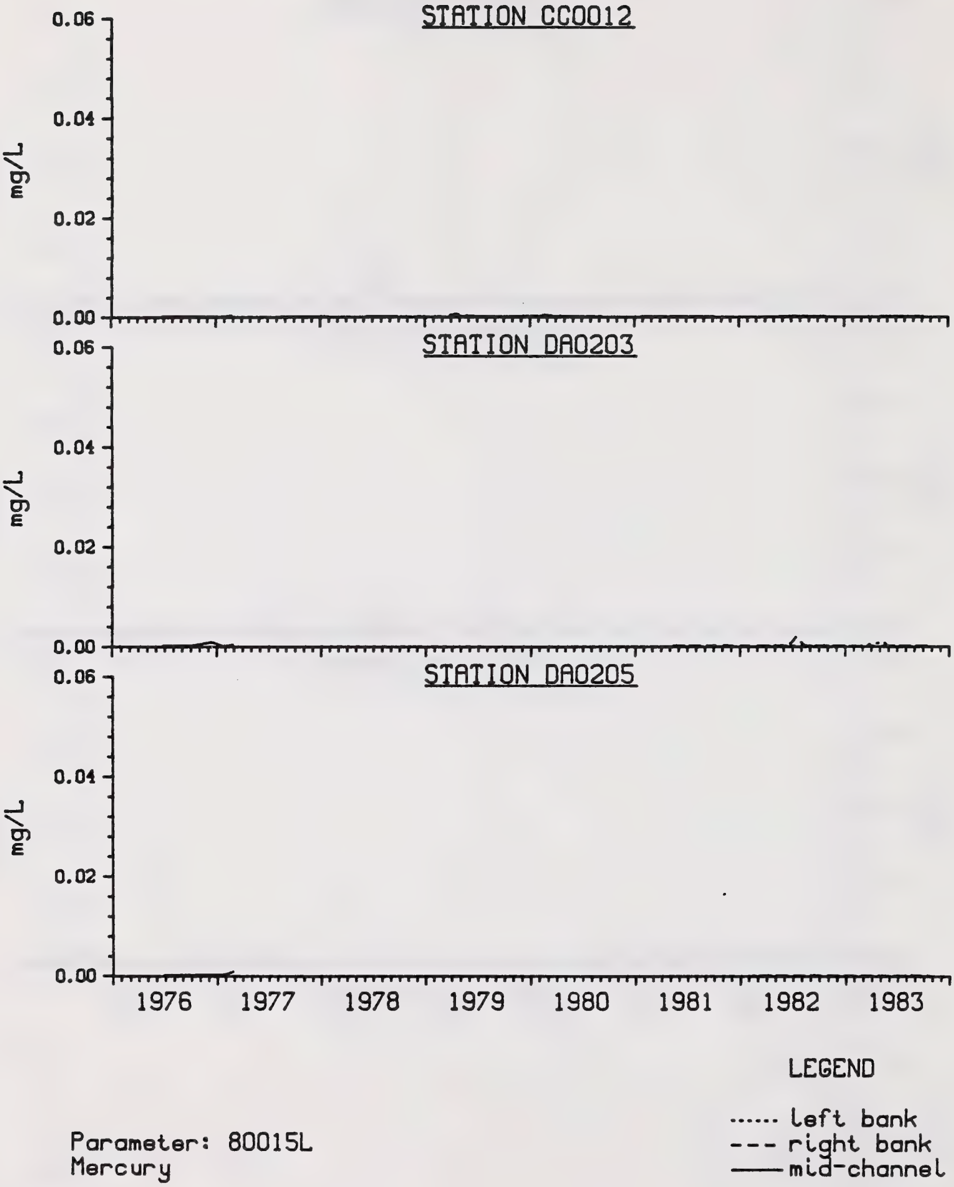


Figure 70. Mercury at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

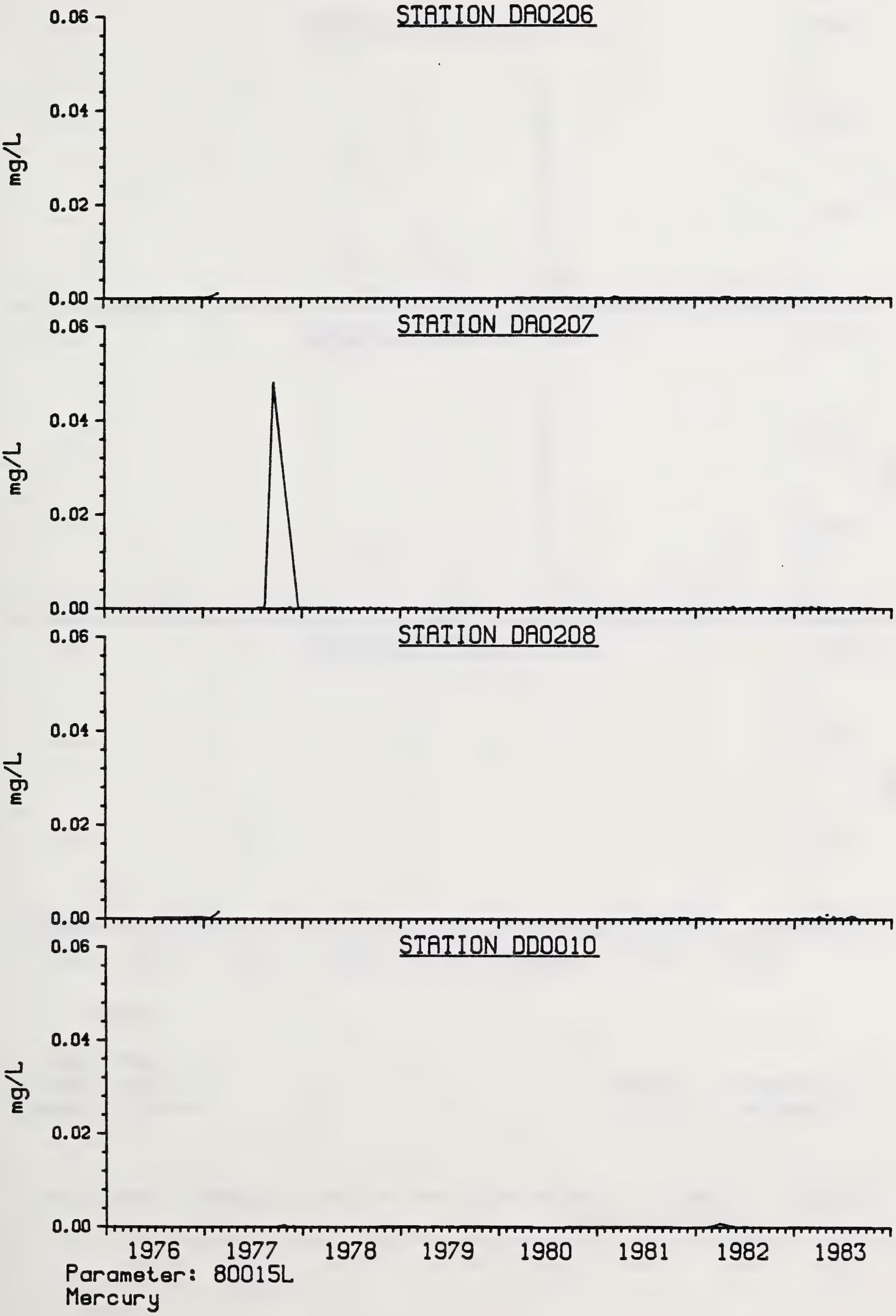


Figure 70. Concluded.

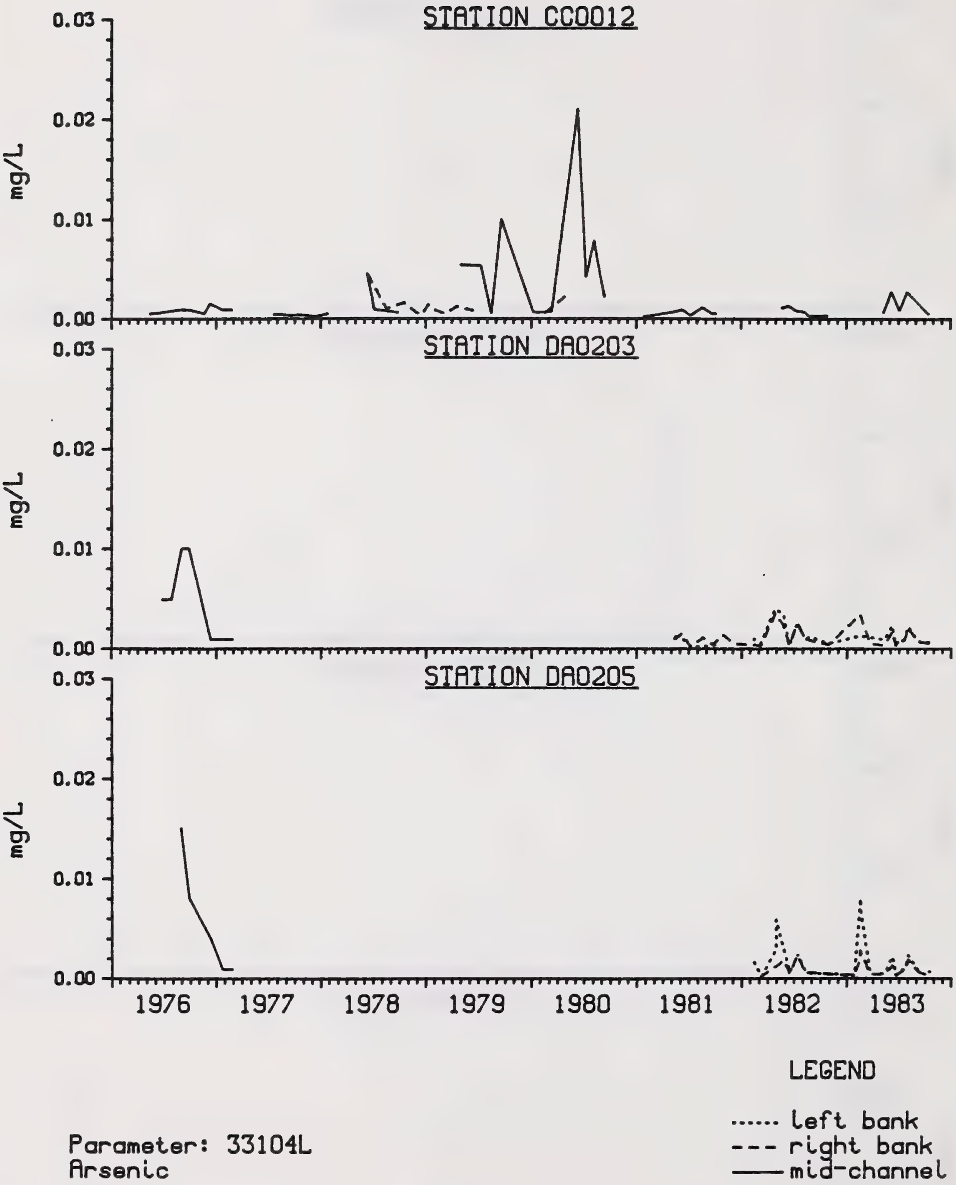


Figure 71. Arsenic at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

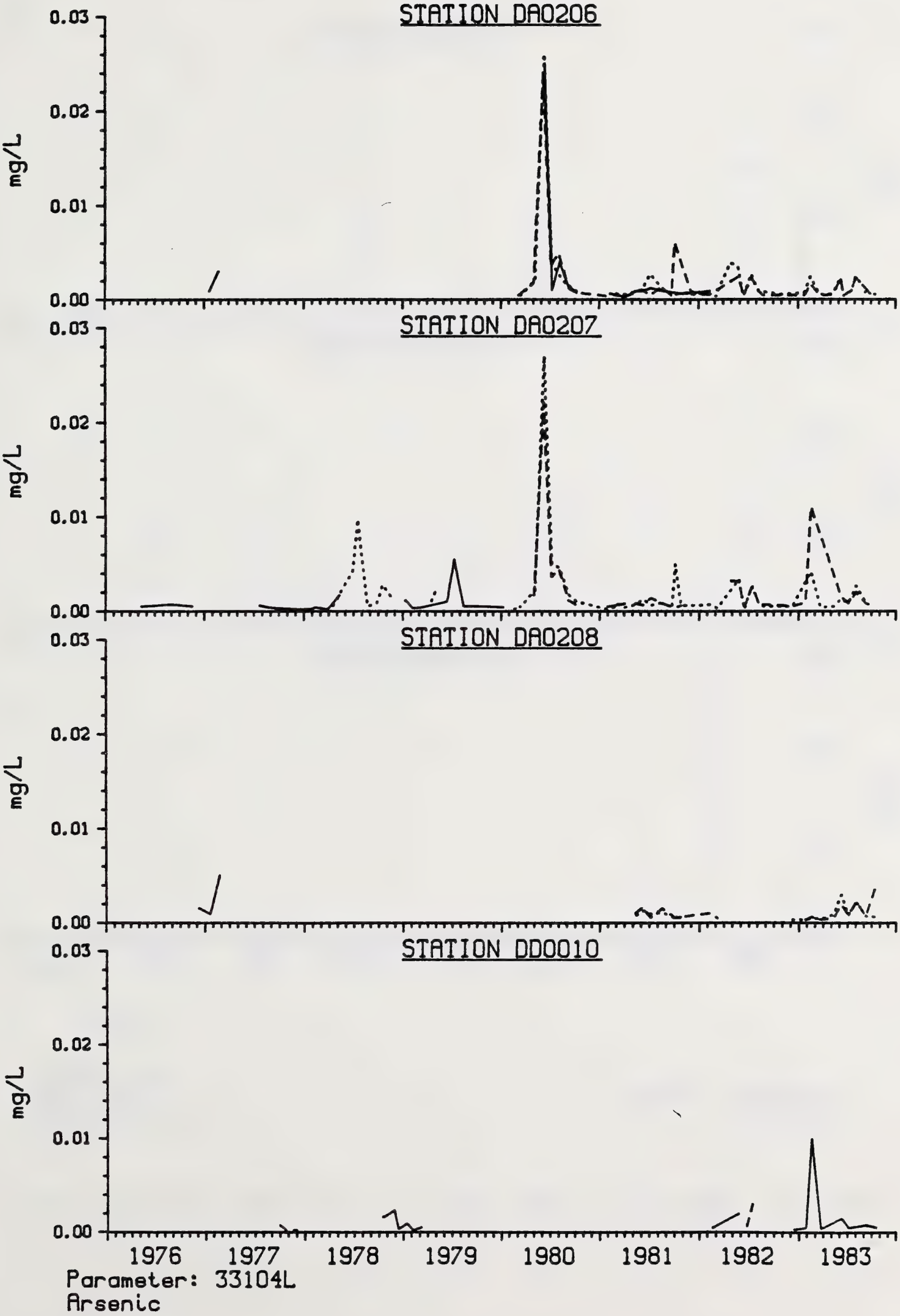


Figure 71. Concluded.

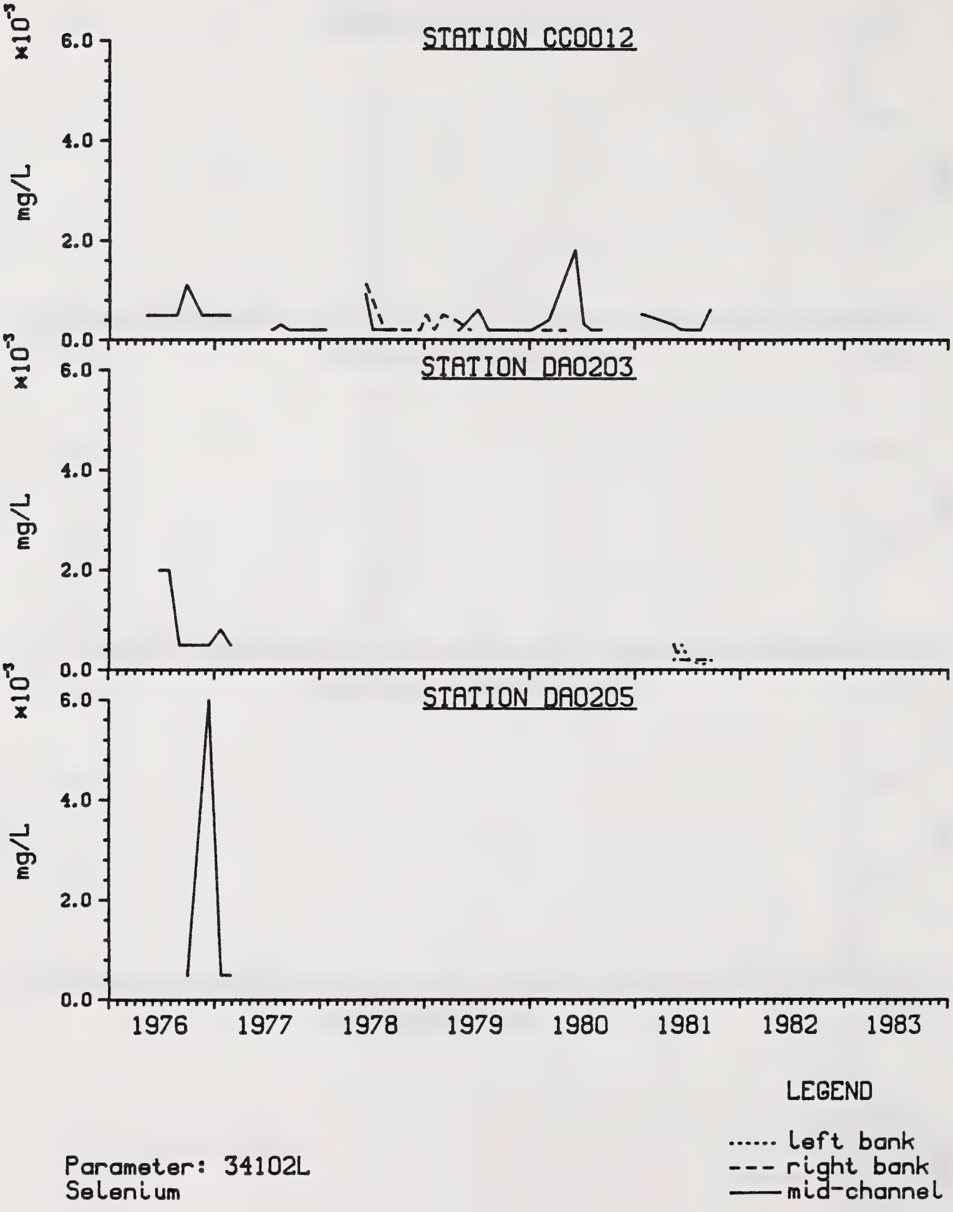


Figure 72. Selenium at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

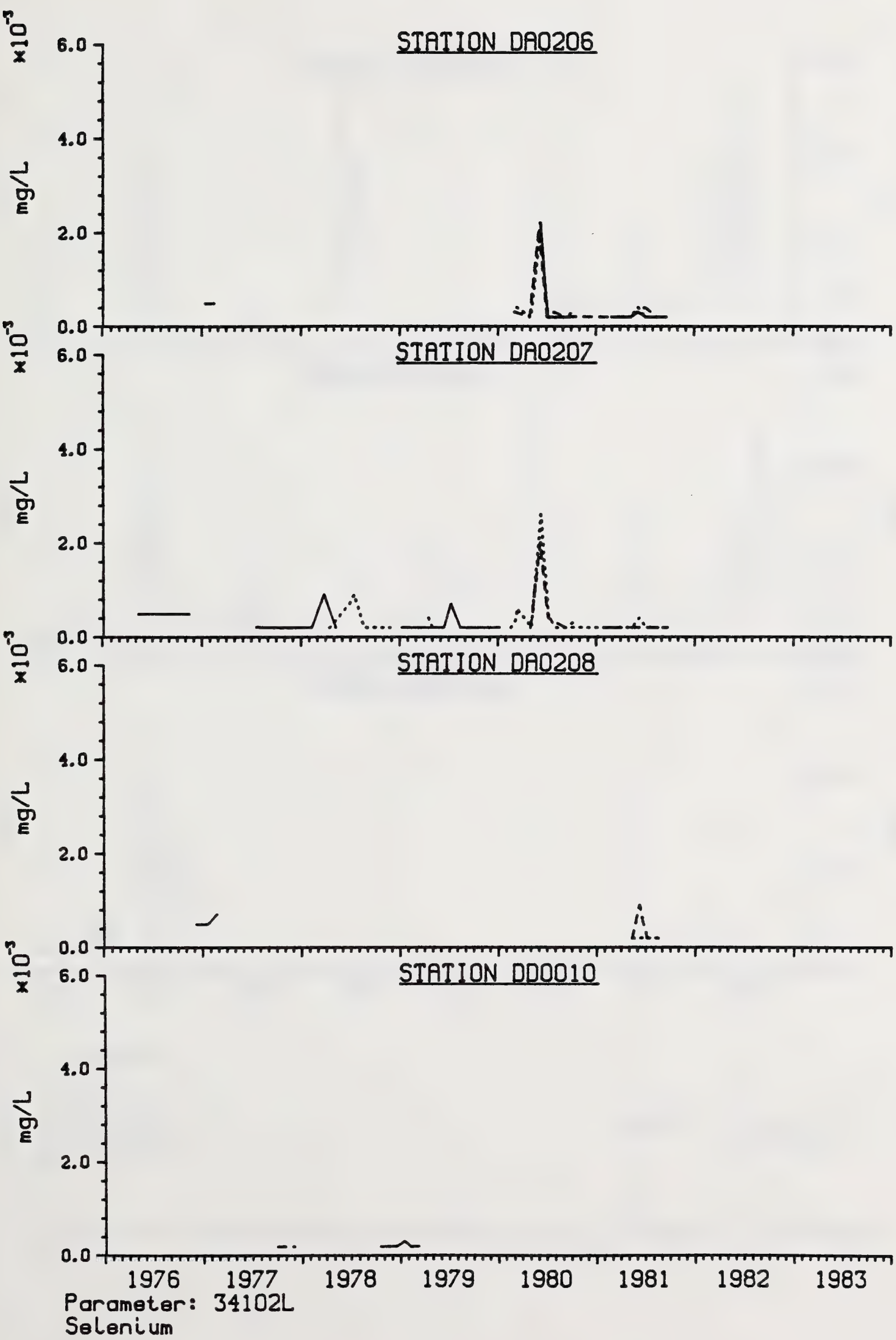


Figure 72. Concluded.

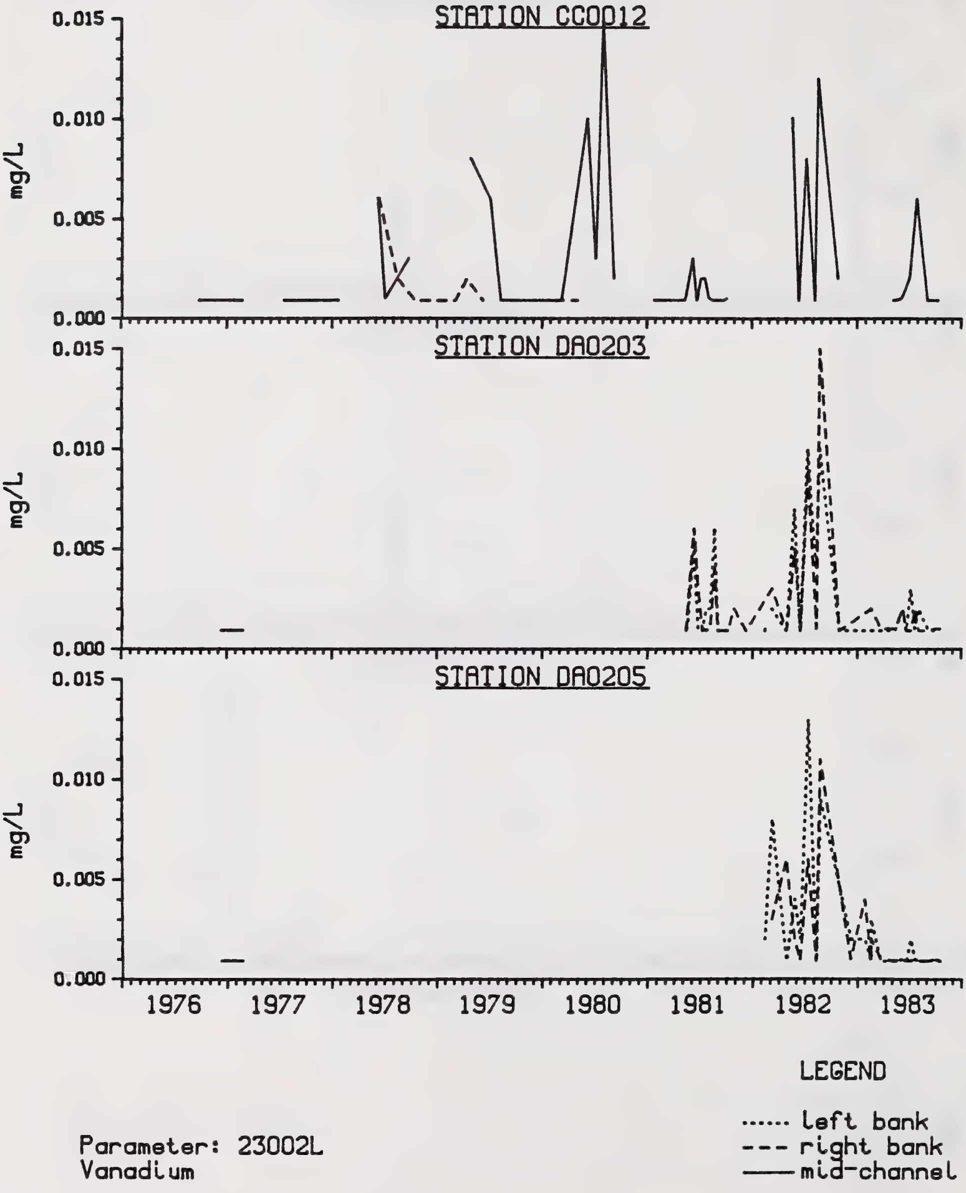


Figure 73. Vanadium at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

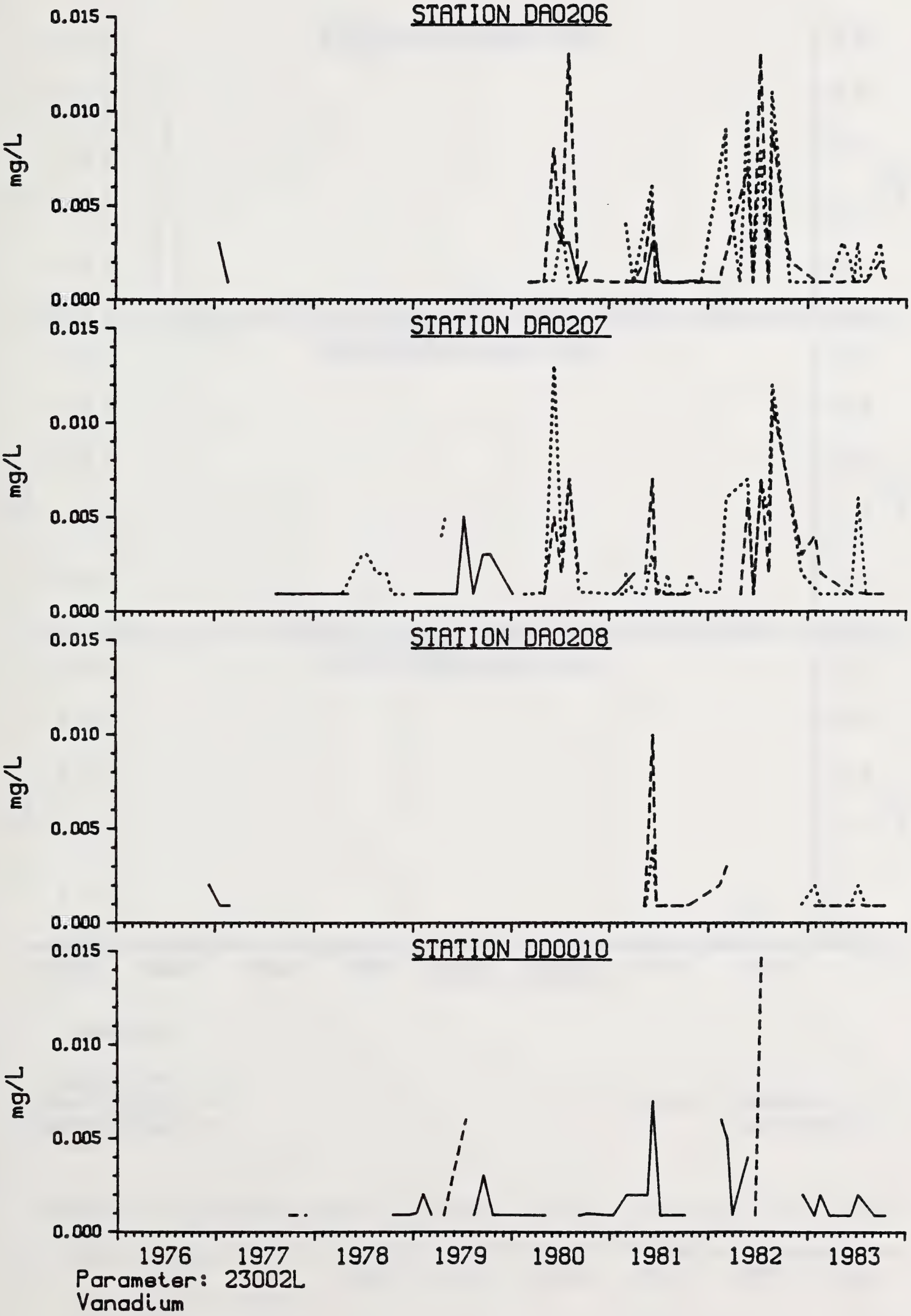


Figure 73. Concluded.

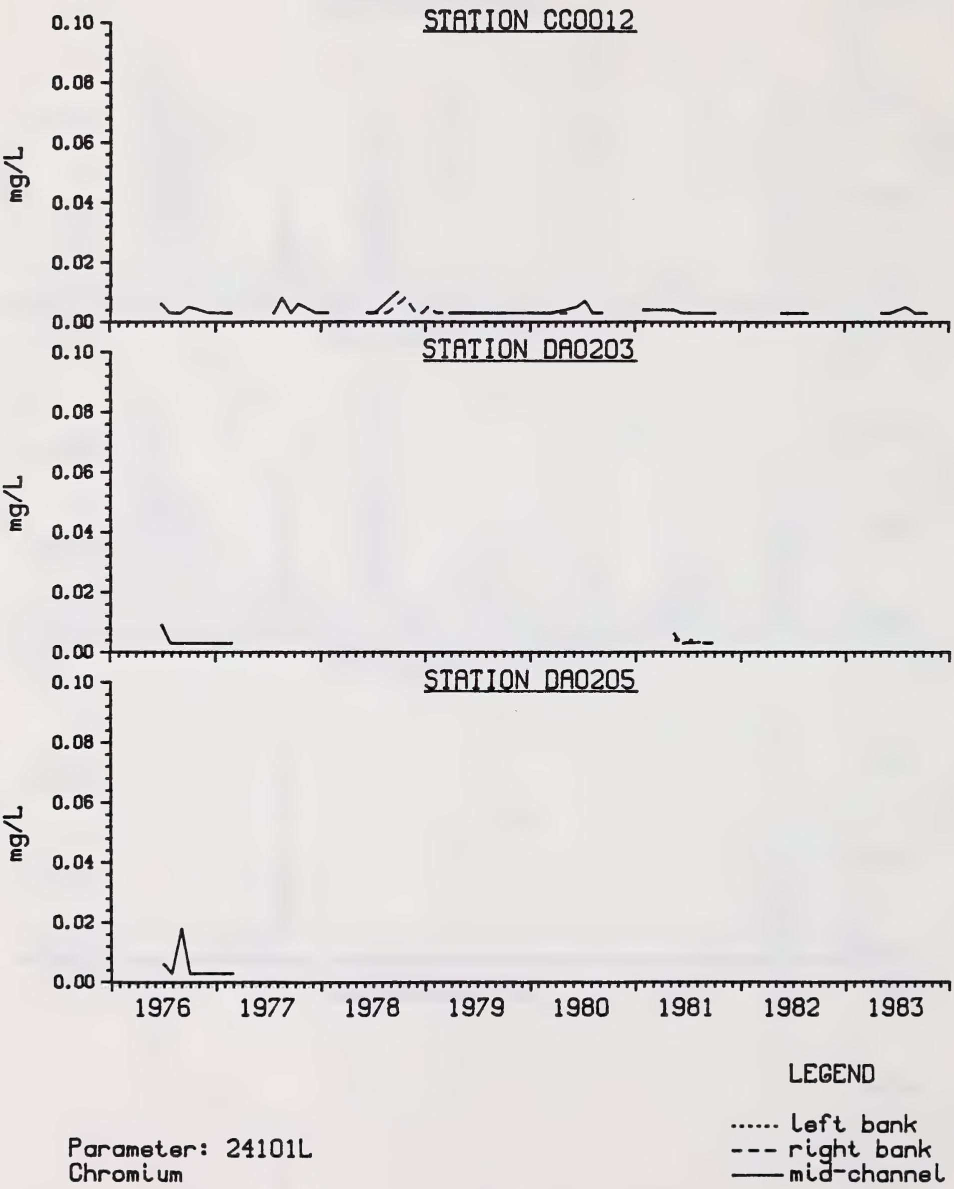


Figure 74. Chromium at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

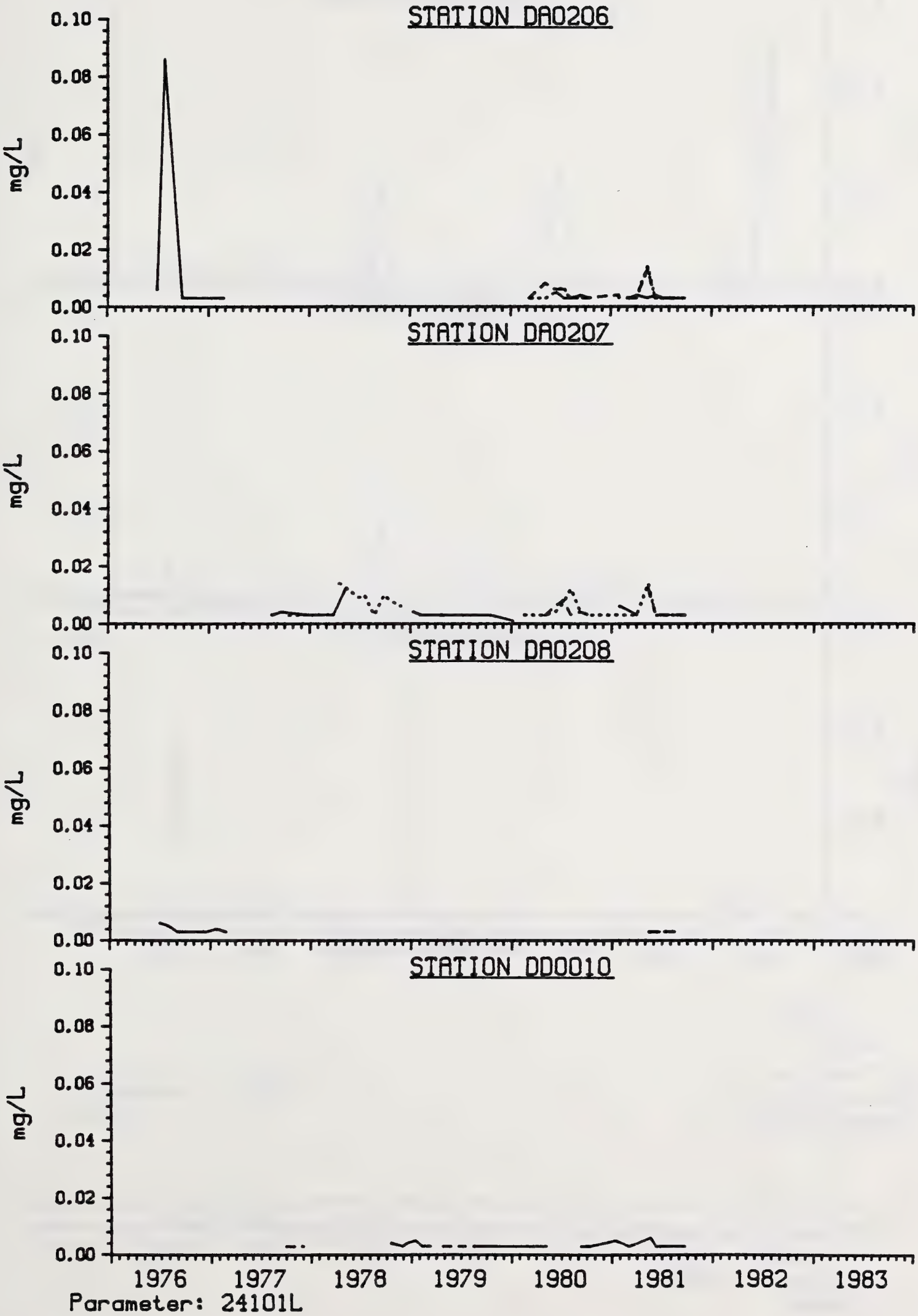
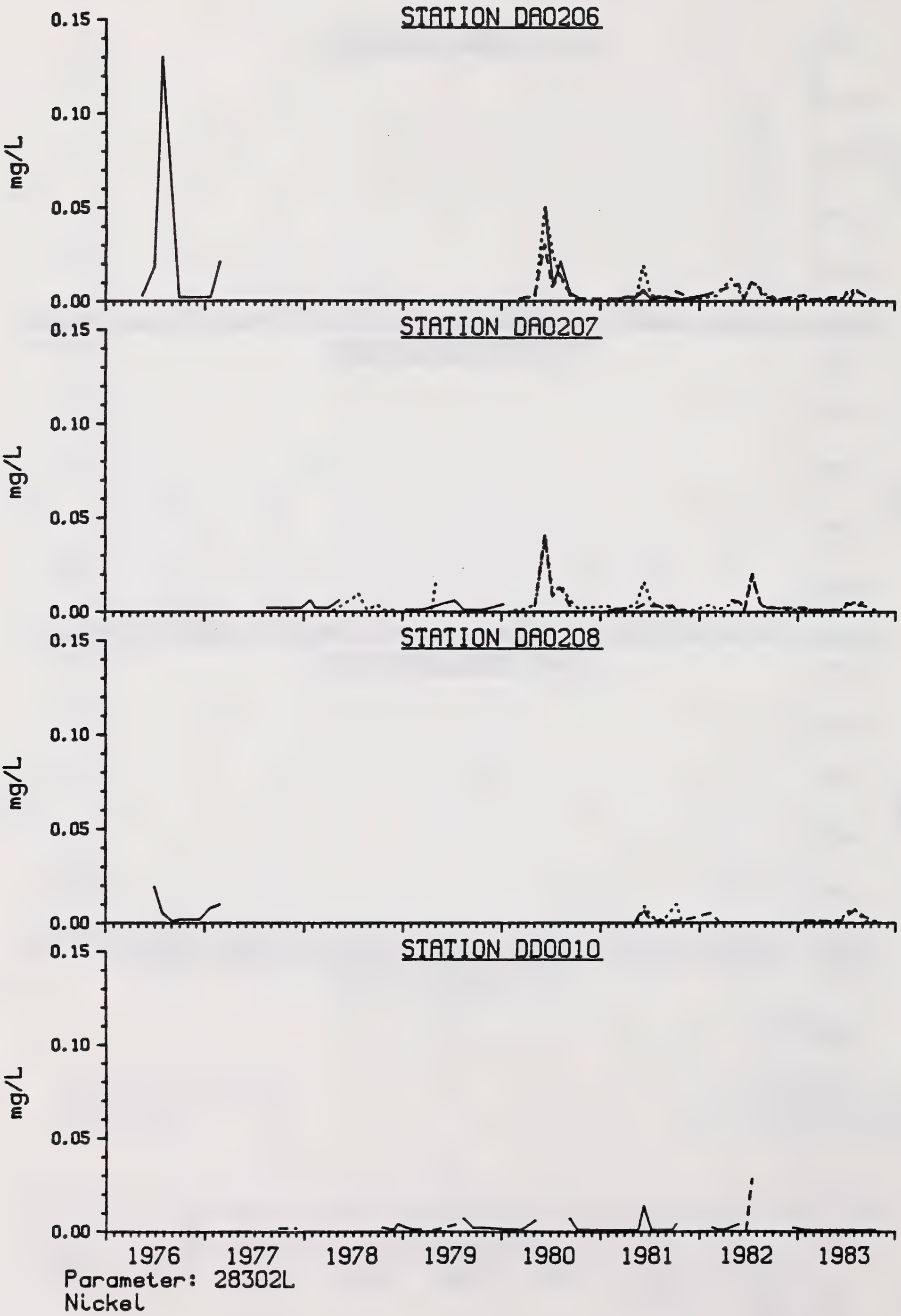


Figure 74. Concluded.



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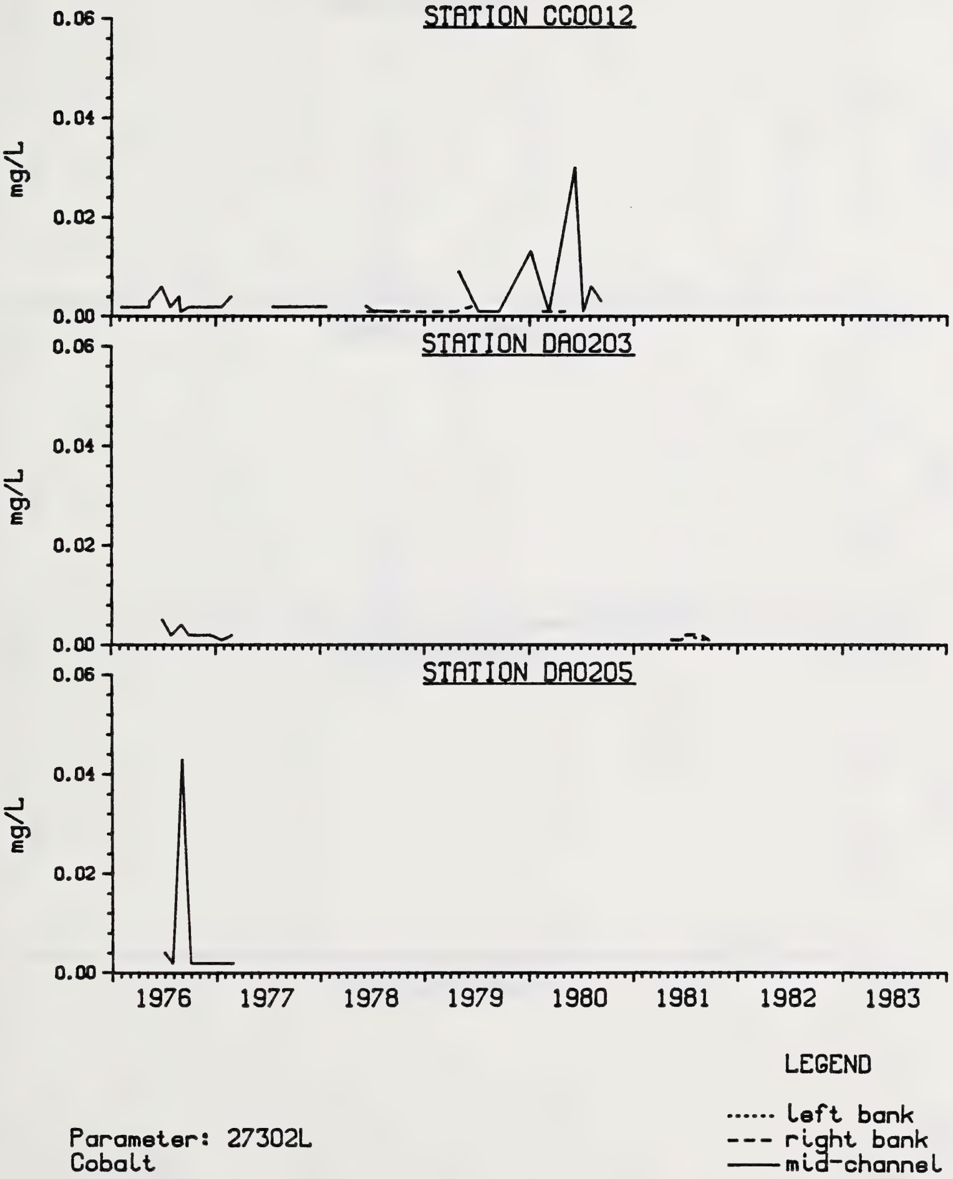


Figure 76. Cobalt at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

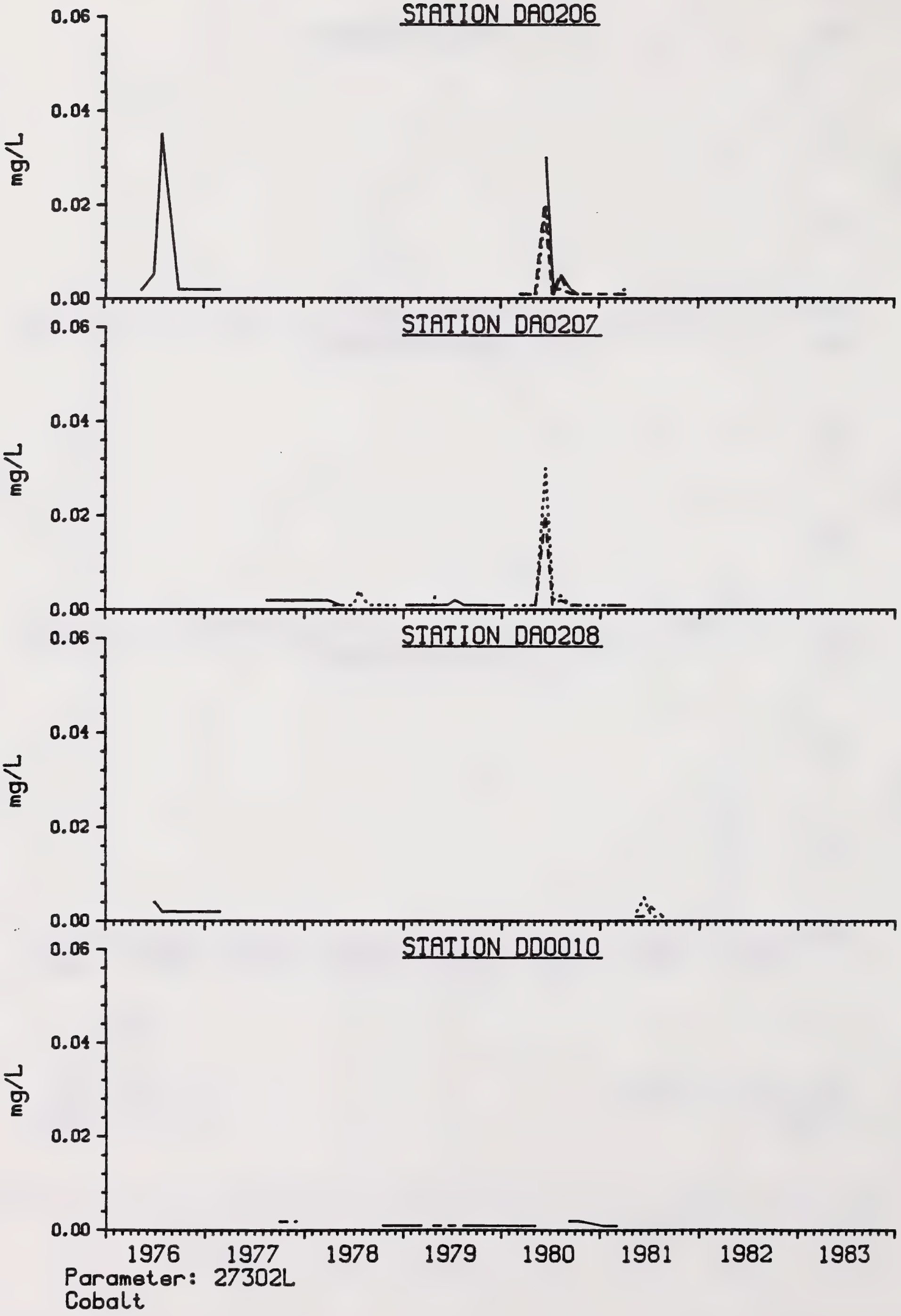


Figure 76. Concluded.

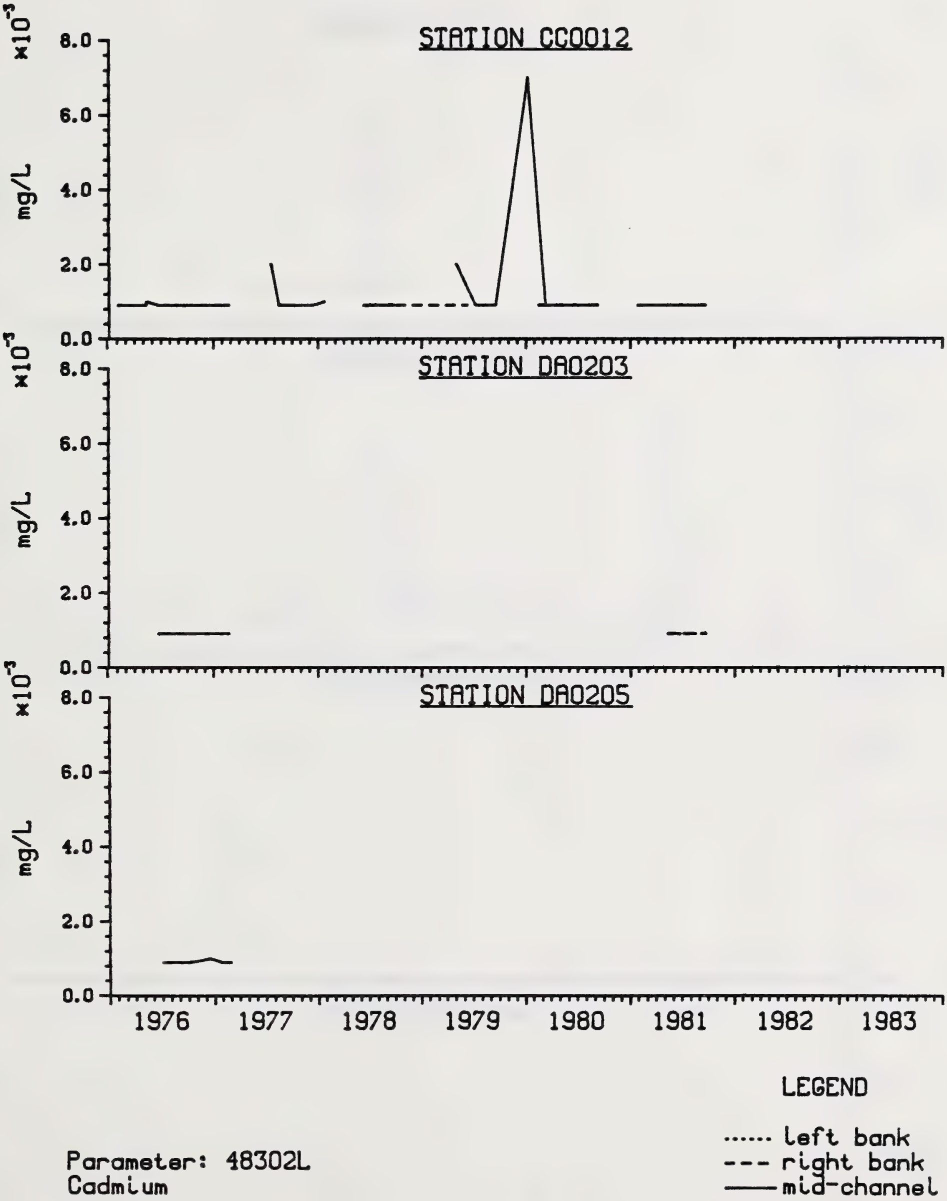
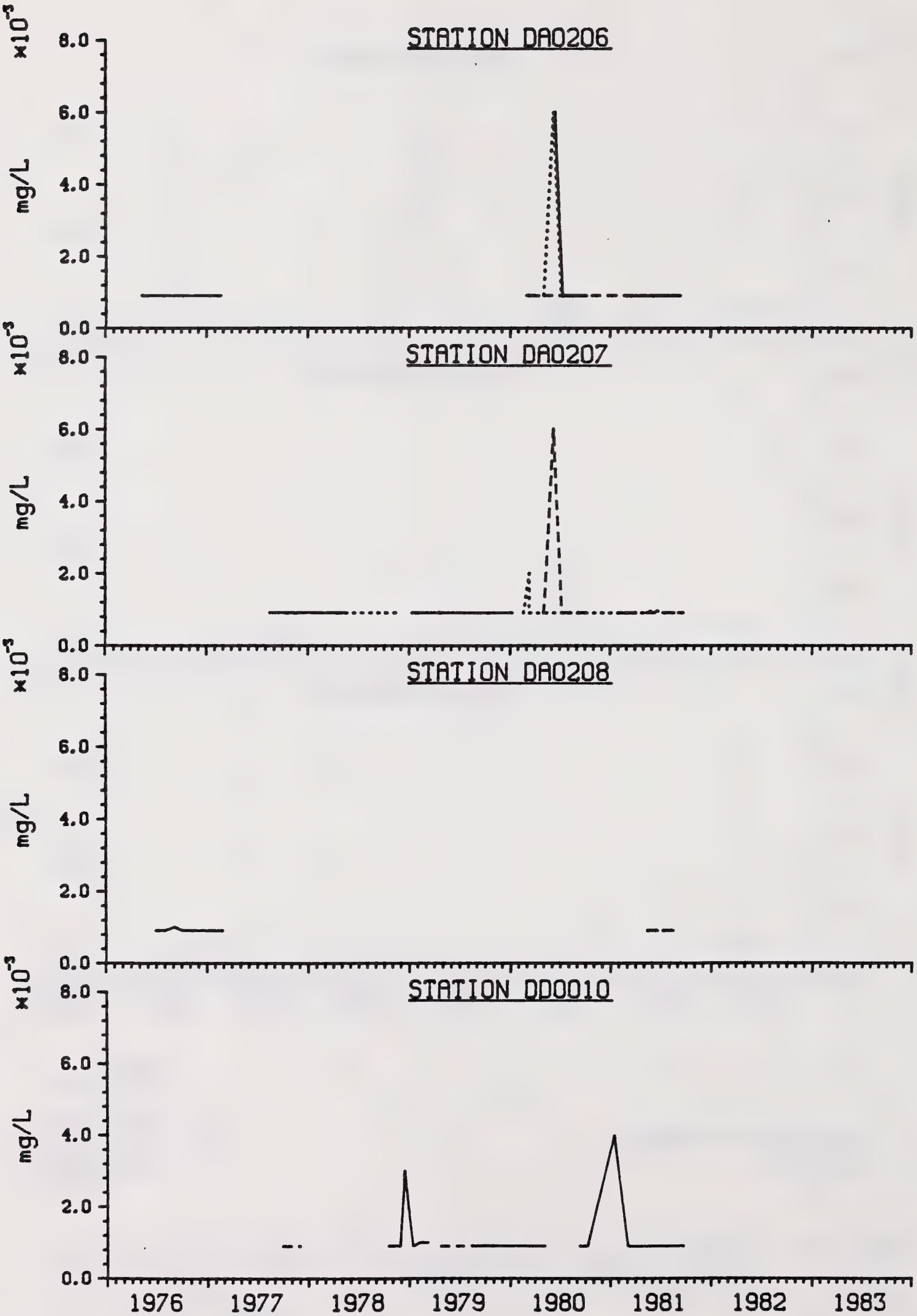


Figure 77. Cadmium at seven stations on the Athabasca River from 1976 to 1983.

concluded . . .



Parameter: 48302L
Cadmium

Figure 77. Concluded.

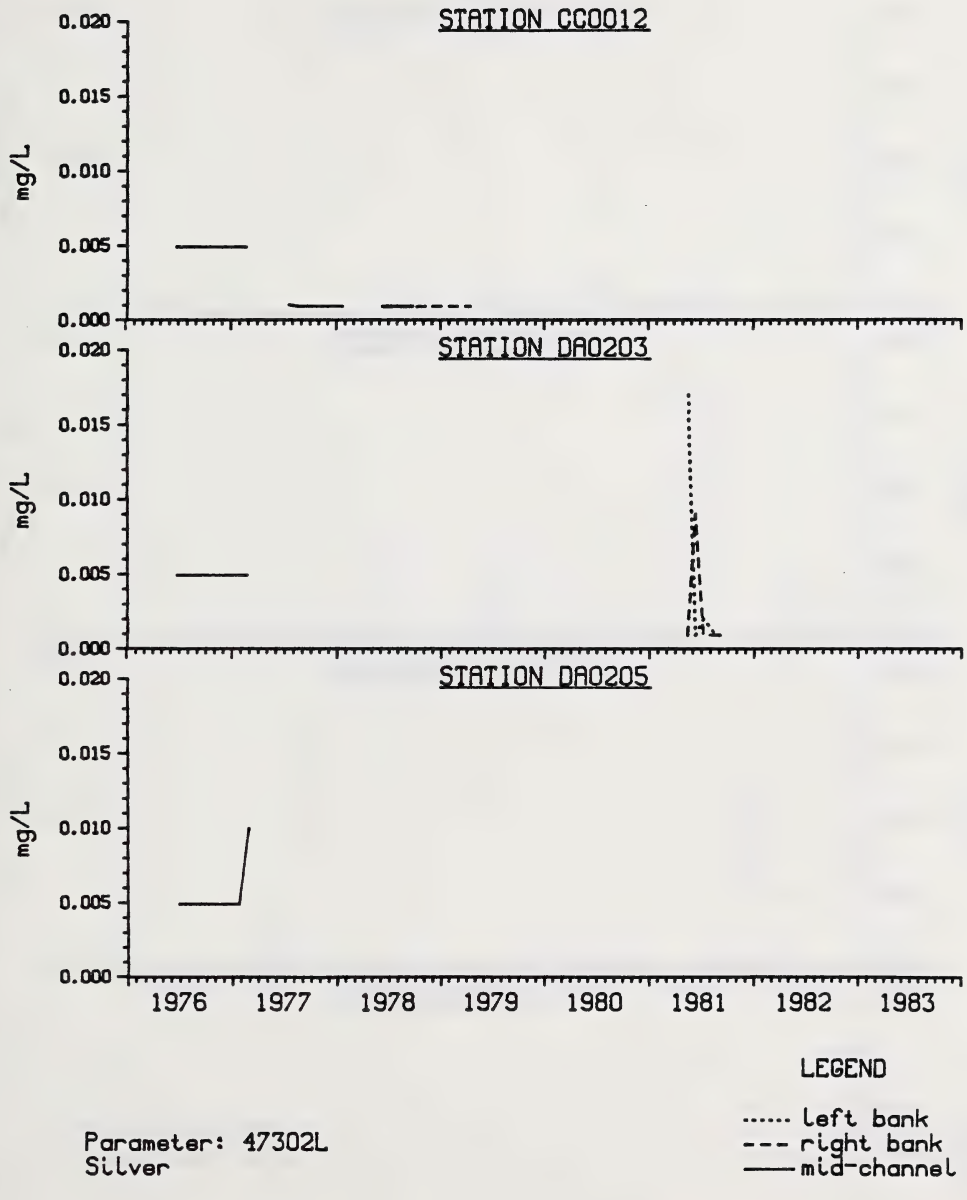


Figure 78. Silver at seven stations on the Athabasca River from 1976 to 1983.

concluded . . .

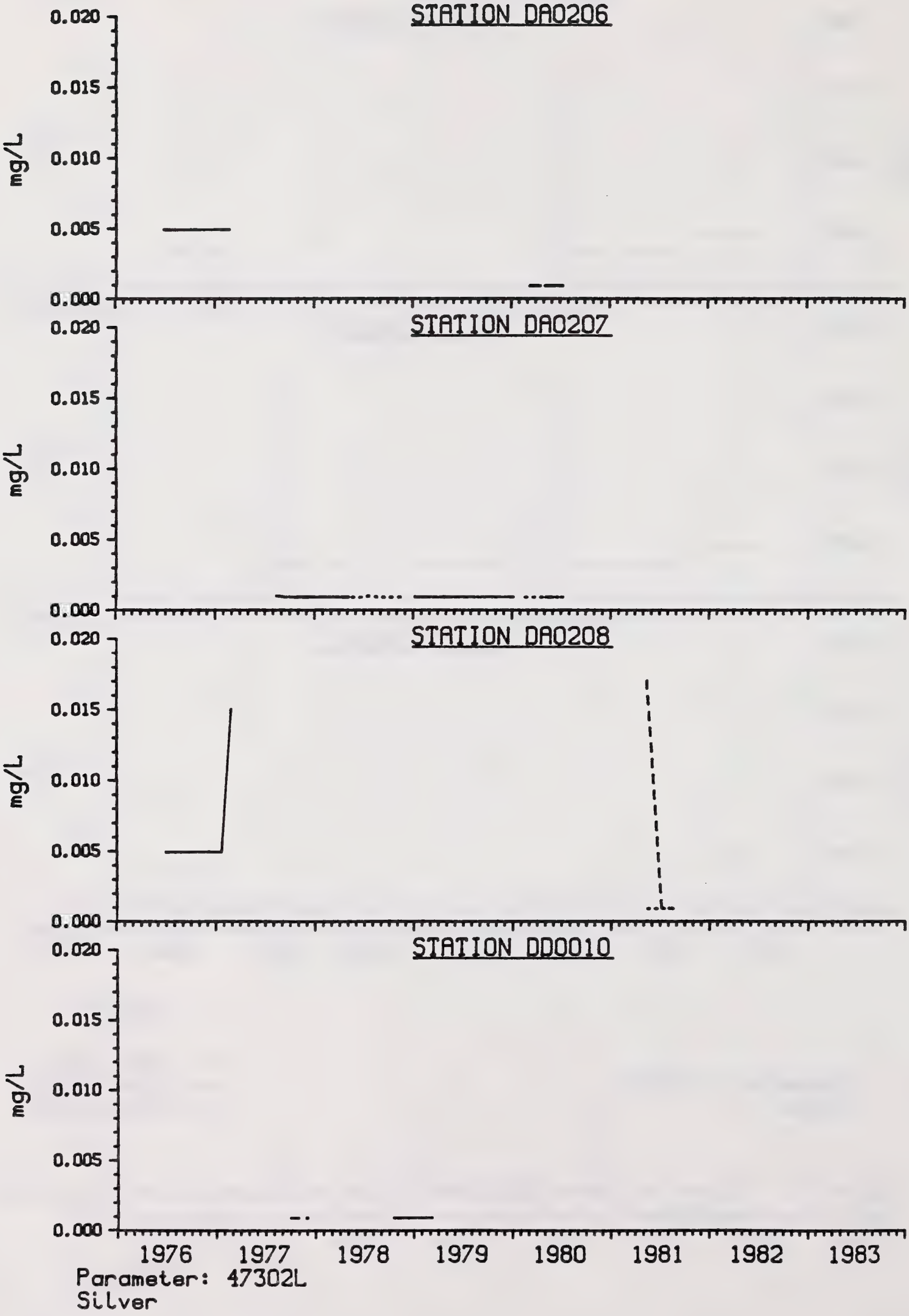


Figure 78. Concluded.

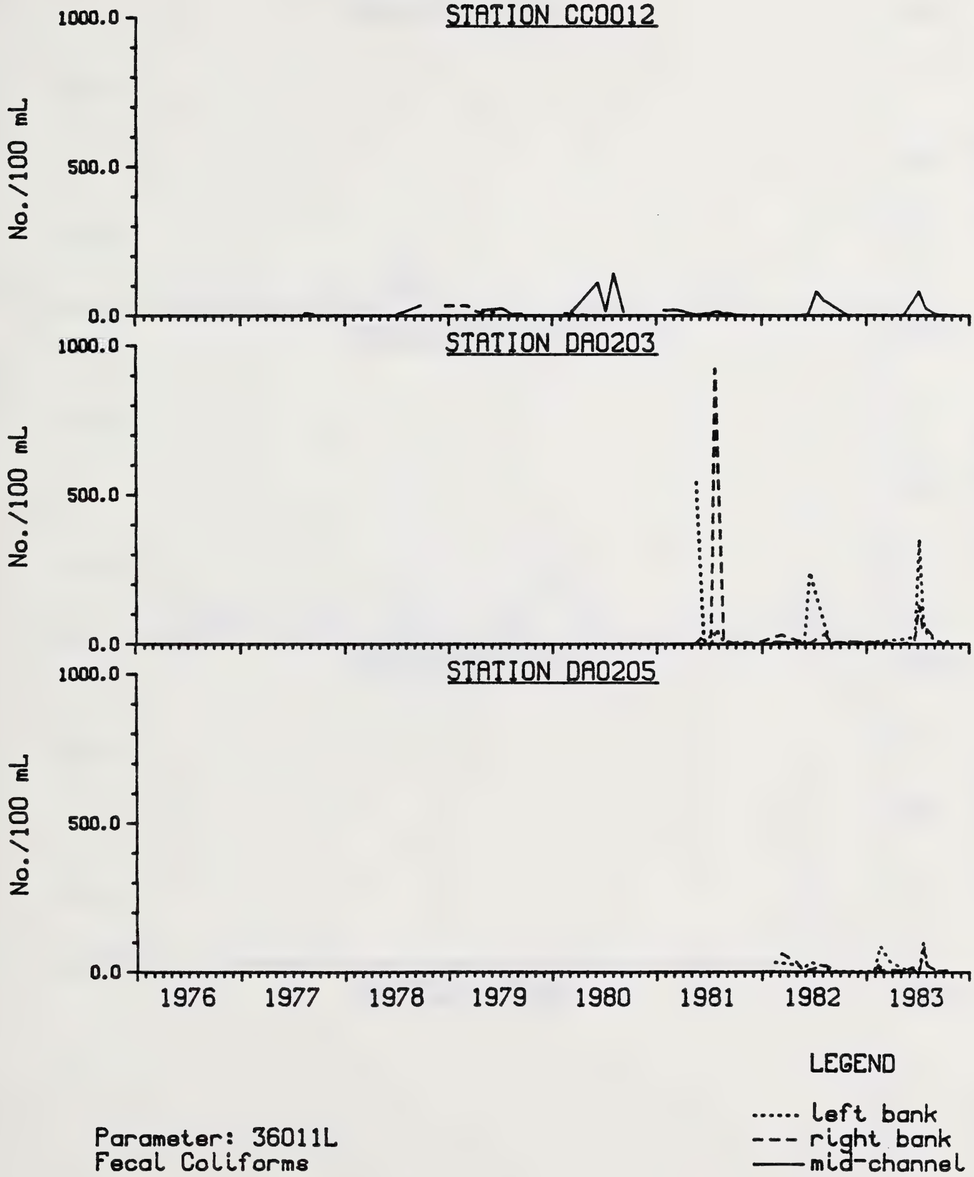


Figure 79. Fecal coliform bacteria at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

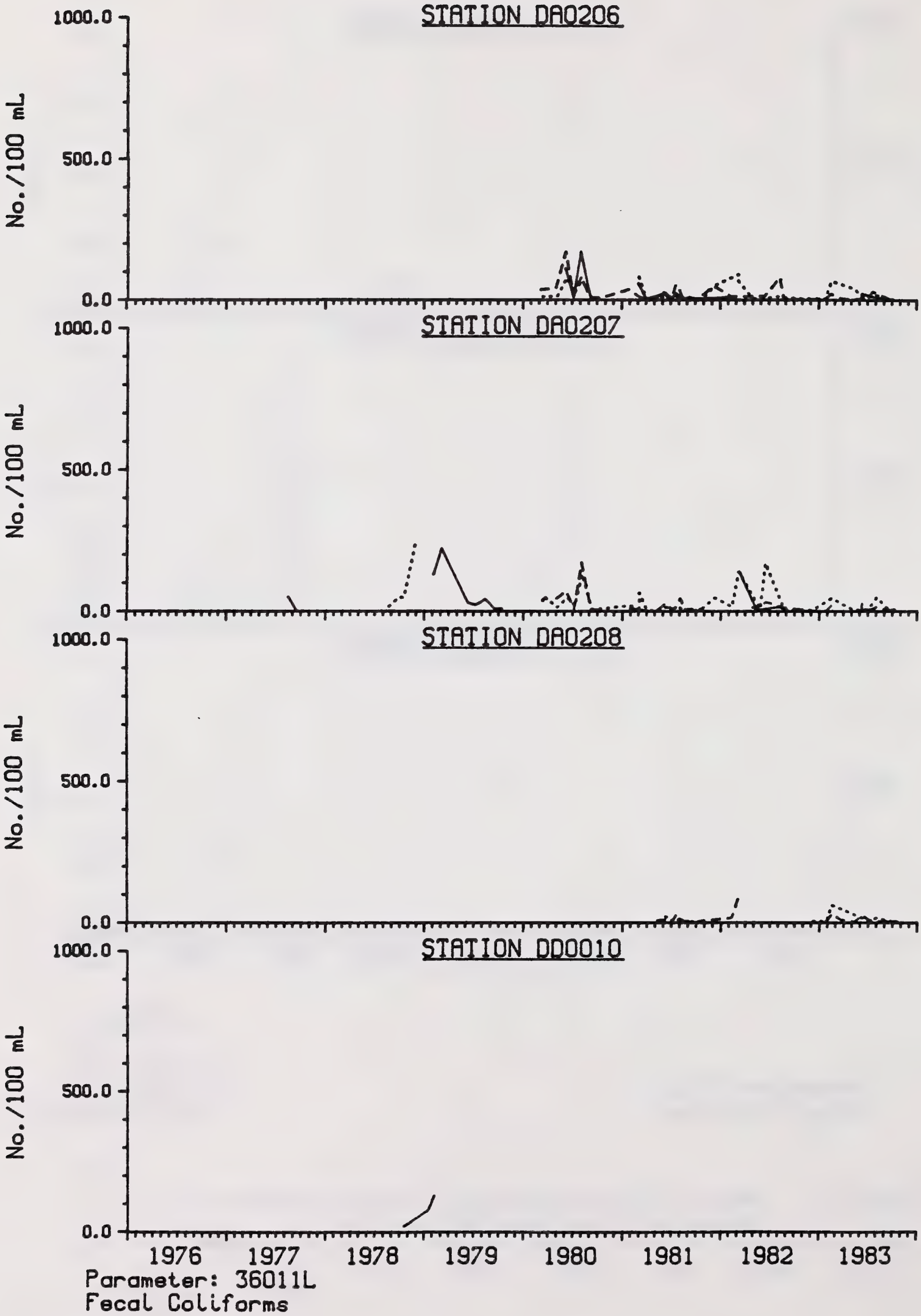


Figure 79. Concluded.

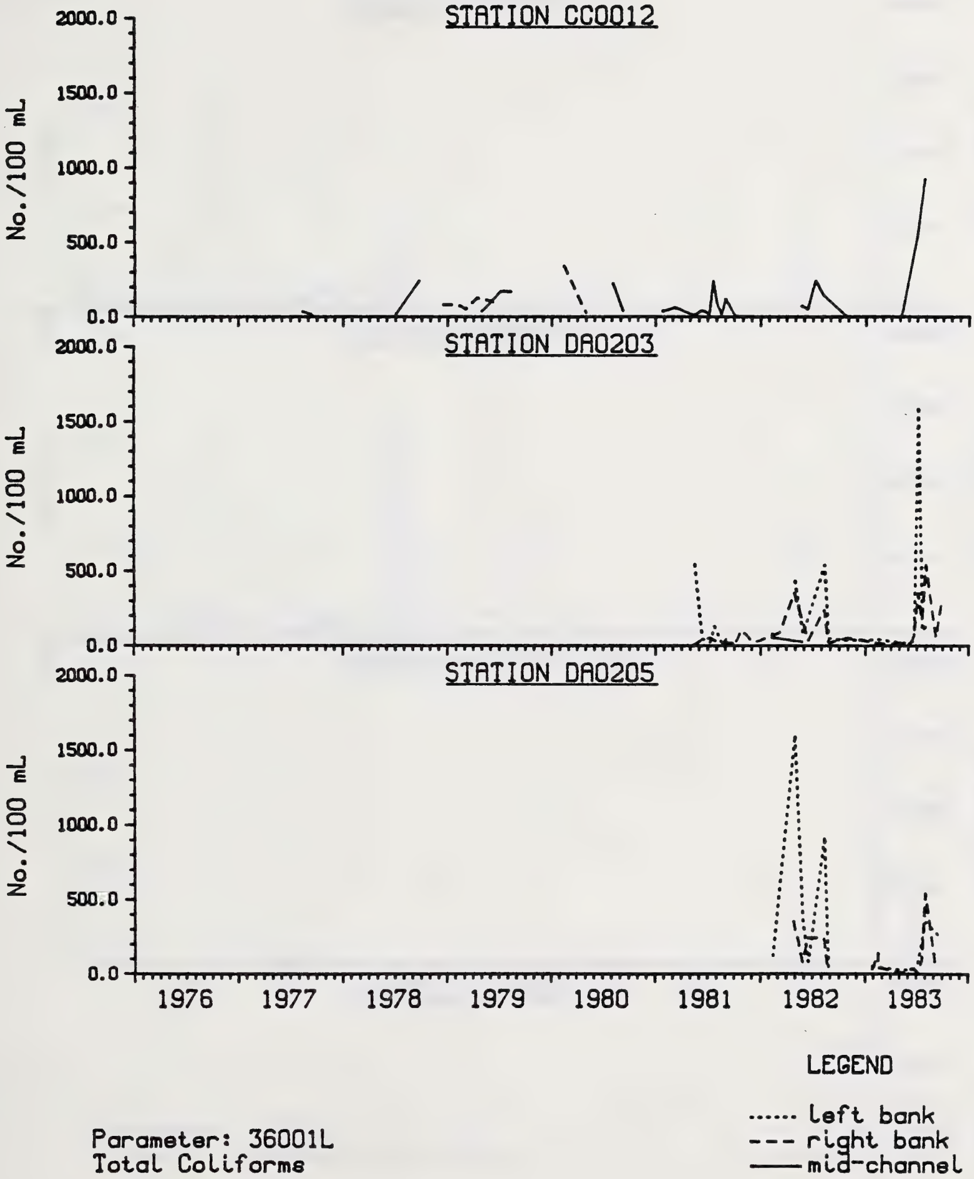


Figure 80. Total coliform bacteria at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

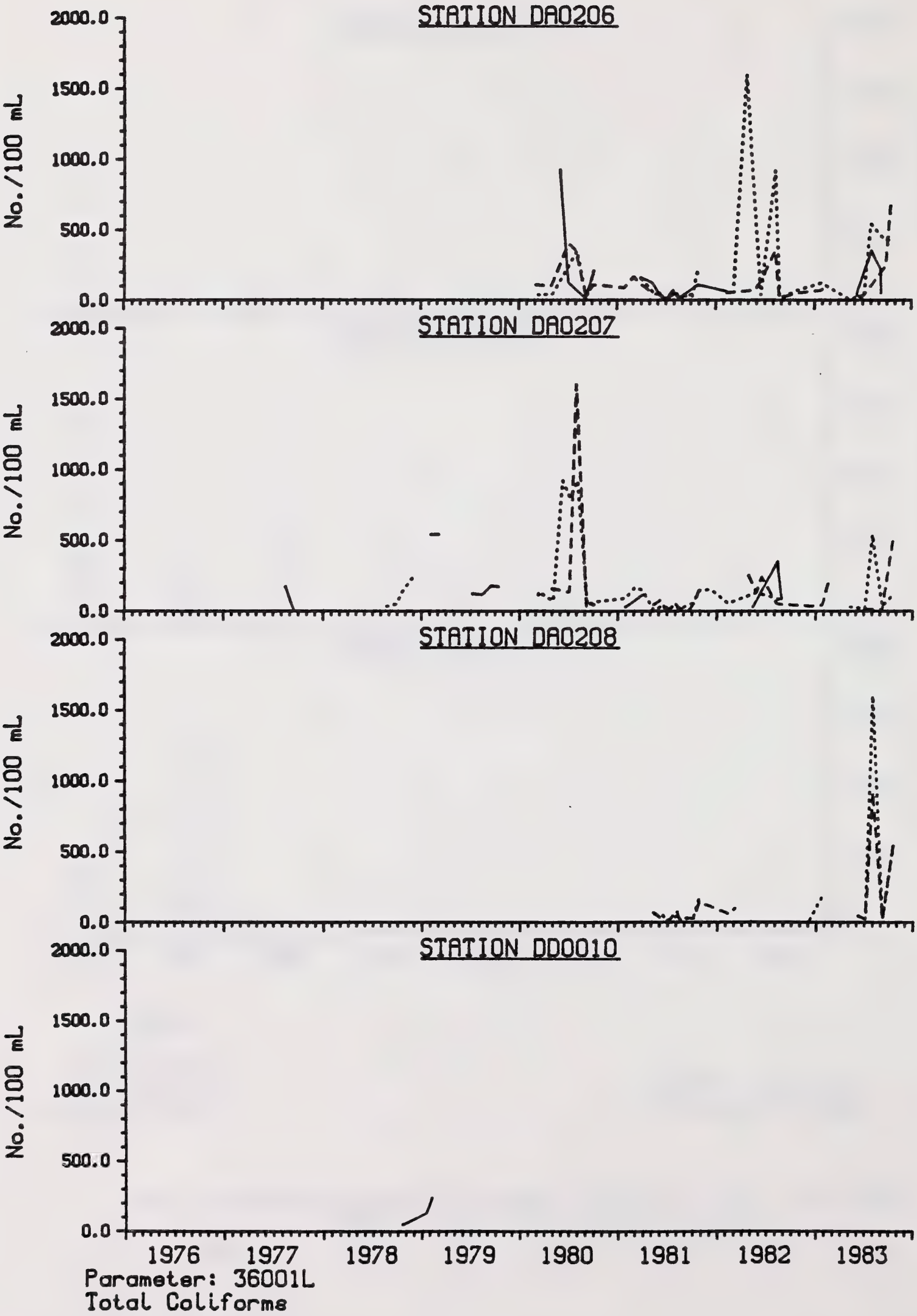


Figure 80. Concluded.

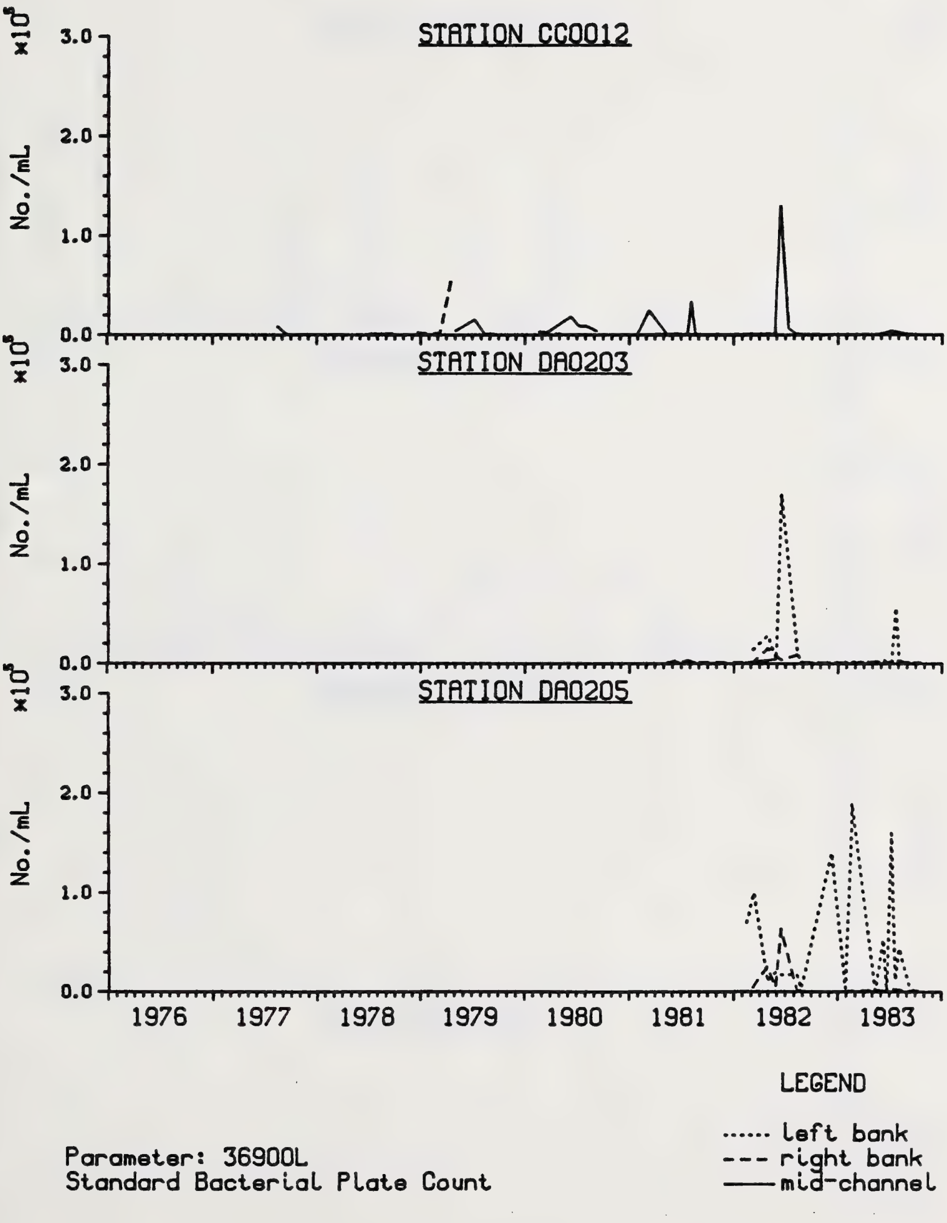


Figure 81. Standard bacterial plate counts at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

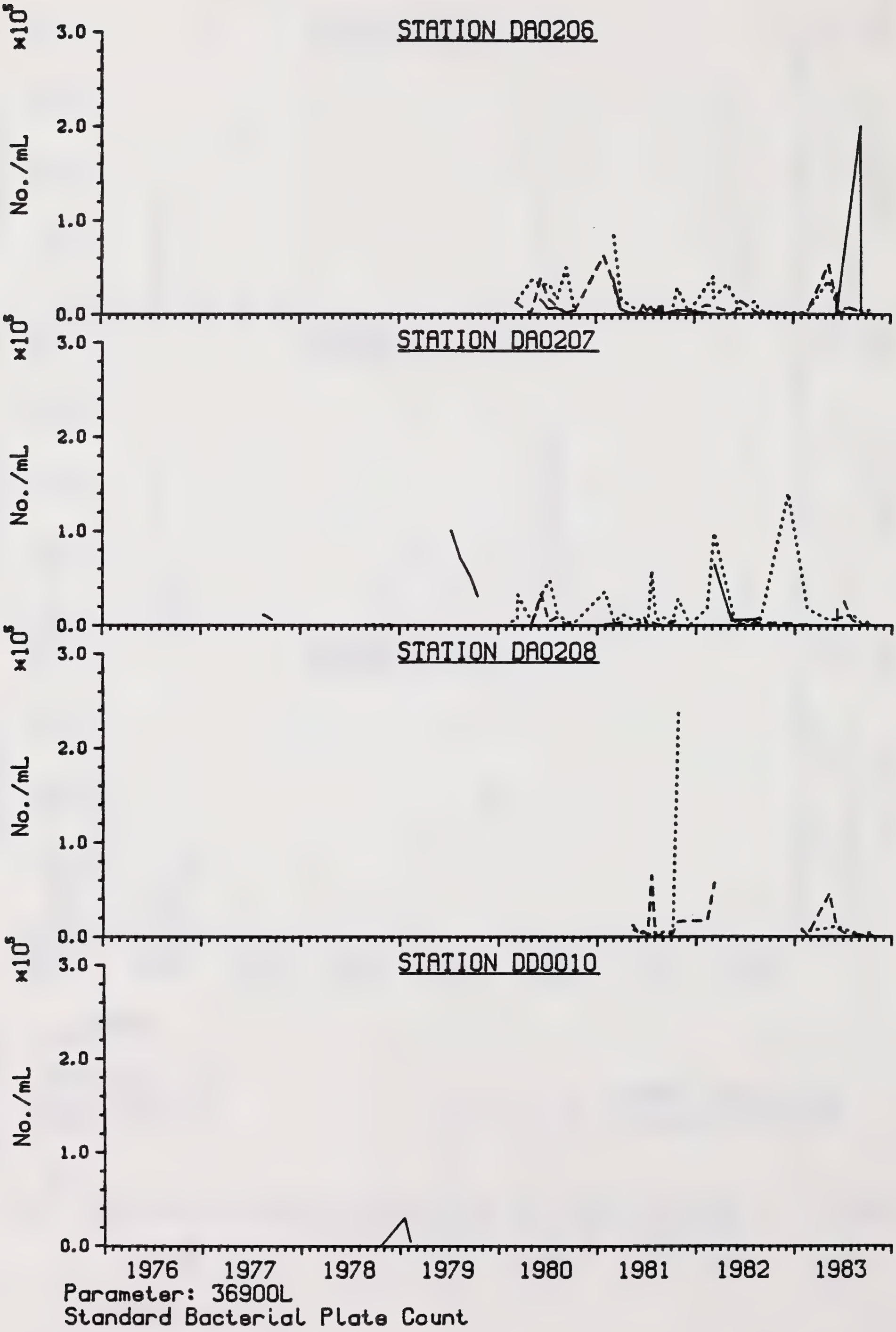


Figure 81. Concluded.

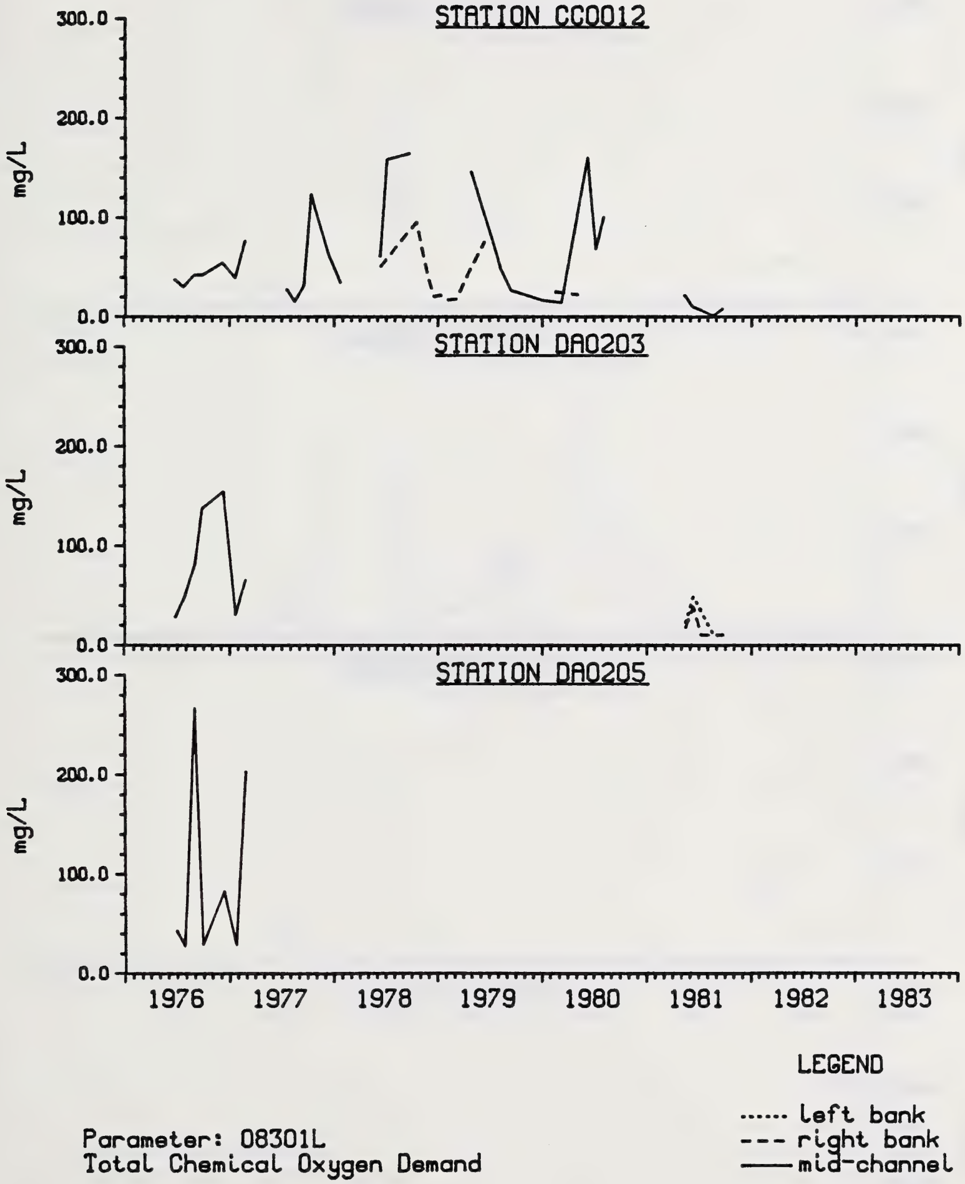


Figure 82. Chemical oxygen demand at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

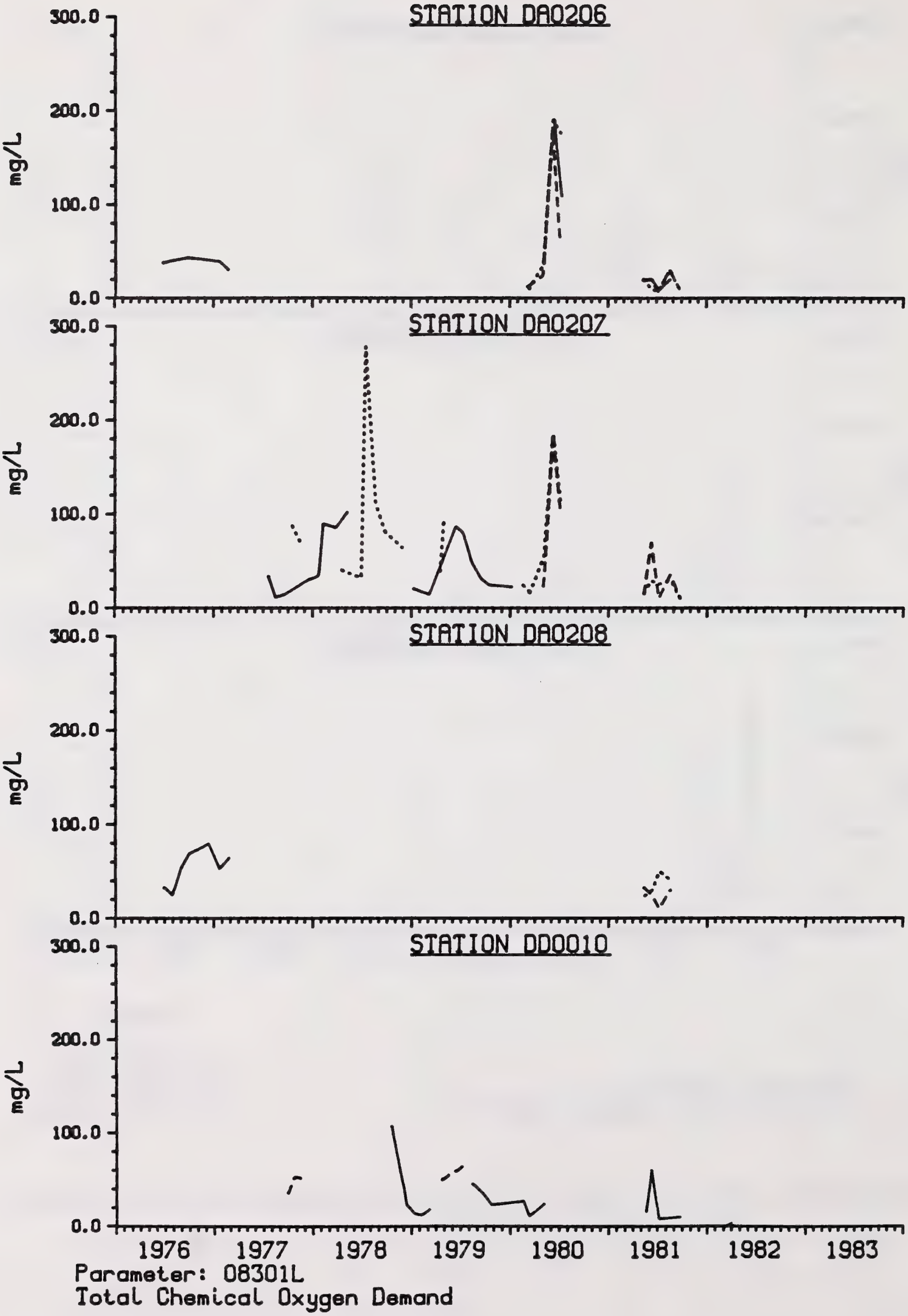


Figure 82. Concluded.

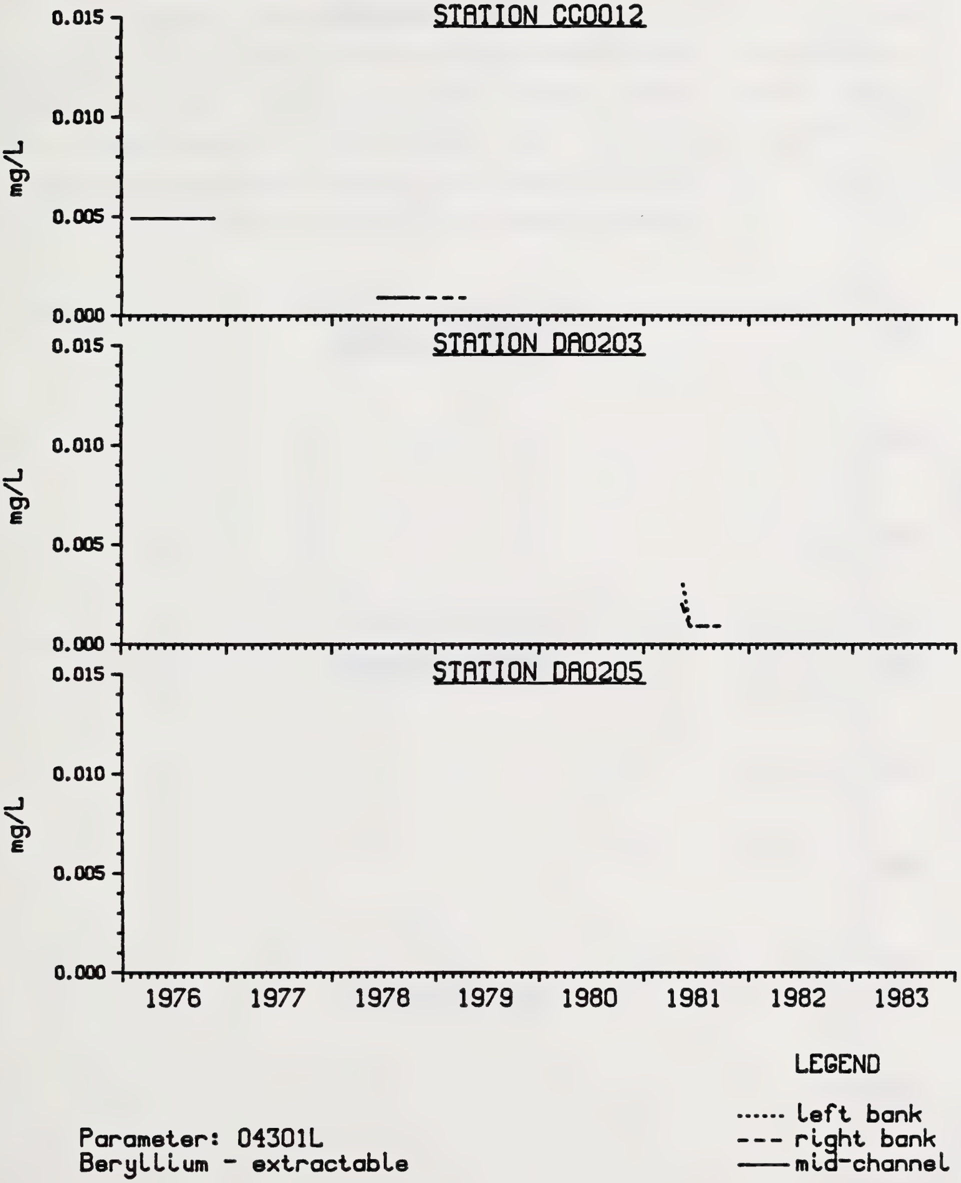


Figure 83. Beryllium at seven stations on the Athabasca River from 1976 to 1983.

continued . . .

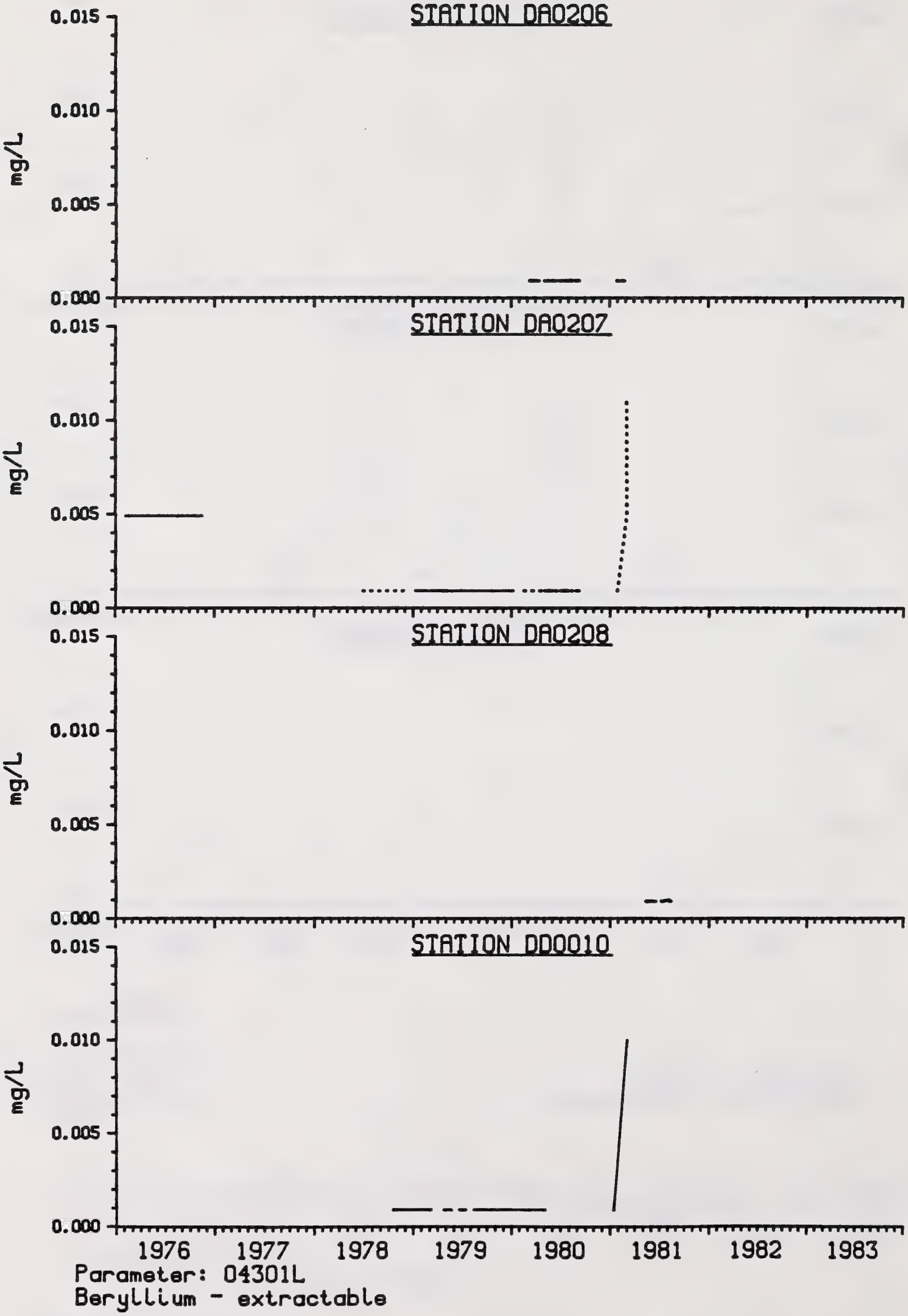


Figure 83. Concluded.

7.2 BENTHIC INVERTEBRATE ABUNDANCE DATA

Benthic invertebrate abundance data for 16 sites on the Athabasca River during the spring and summer of 1981 are presented in tables 20 to 23. The data are from Boerger (1983), and for each of May, June, and July, the samples from two sampling periods were pooled for calculating means and standard deviations. The August data includes samples from only one sampling period.

Table 20. Benthic invertebrate abundance (number/m^2) at 16 sites on the Athabasca River between May 13 and May 29, 1981. Values are means and standard deviations based on 6 samples from each station.

Taxon	Station 1E		Station 1W		Station 2E		Station 2W		Station 3E		Station 3W		Station 4E		Station 4W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Nematomorpha	3.3	8.2	0.0	0.0	11.7	28.6	3.3	5.2	3.3	5.2	0.0	0.0	0.0	0.0	0.0	0.0
Oligochaeta	20.0	21.0	10.0	16.7	8.3	7.5	26.7	51.3	45.0	79.4	6.7	16.3	86.7	104.2	1.7	4.1
Hirudinea																
Erpobdellidae																
Nephelopsis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gastropoda																
Lymnaeidae																
Lymnaea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0
Bivalvia																
Sphaeriidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydracarina	0.0	0.0	0.0	0.0	0.0	0.0	10.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cladocera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostracoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Copepoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Collembola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0
Ephemeroptera																
Siphlonuridae																
Ameletus	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	1.7	4.1	8.3	20.4	1.7	4.1	5.0	8.4
Siphlonurus	1.7	4.1	3.3	8.2	10.0	15.5	15.0	32.1	0.0	0.0	10.0	16.7	0.0	0.0	0.0	0.0
Baetidae																
Baetis sp. A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetis sp. B	6.7	16.3	3.3	5.2	0.0	0.0	3.3	5.2	1.7	4.1	0.0	0.0	11.7	19.4	0.0	0.0
Baetis sp. X	0.0	0.0	3.3	8.2	3.3	8.2	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloeon sp. 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	12.2	0.0	0.0	5.0	8.4	0.0	0.0
Cloeon sp. 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pseudocloeon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	1.7	4.1	0.0	0.0
Heptageniidae																
Heptagenia	103.3	214.5	8.3	11.7	20.0	20.0	0.0	0.0	25.0	47.2	10.0	12.6	20.0	19.0	6.7	8.2
Rhithrogena	5.0	8.4	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	5.0	8.4	0.0	0.0	3.3	5.2

continued . . .

Table 20. Continued.

Taxon	Station 1E		Station 1W		Station 2E		Station 2W		Station 3E		Station 3W		Station 4E		Station 4W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Ametropodidae																
Ametropus	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	1.7	4.1	0.0	0.0	3.3	8.2	0.0	0.0
Metretopodidae																
Metretopus	0.0	0.0	3.3	5.2	15.0	19.7	8.3	11.7	20.0	31.0	11.7	16.0	5.0	8.4	1.7	4.1
Leptophlebiidae																
Leptophlebia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ephemerellidae																
Ephemerella	0.0	0.0	3.3	5.2	8.3	7.5	3.3	8.2	3.3	5.2	1.7	4.1	8.3	7.5	3.3	5.2
Tricorythidae																
Tricorythodes	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Caenidae																
Caenis	0.0	0.0	0.0	0.0	3.3	5.2	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetiscidae																
Baetisca	6.7	8.2	8.3	16.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Odonata																
Gomphidae																
Ophiogomphus	1.7	4.1	5.0	8.4	1.7	4.1	5.0	5.5	0.0	0.0	11.7	11.7	3.3	5.2	6.7	12.1
Plecoptera																
Pteronarcidae																
Pteronarcys	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.2	0.0	0.0	0.0	0.0
Perlodidae	85.0	109.3	41.7	32.5	90.0	70.1	90.0	55.1	51.7	27.9	170.0	192.6	26.7	18.6	85.0	74.5
Hemiptera																
Corixidae	5.0	12.2	3.3	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera																
Dytiscidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1
Elmidae	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichoptera																
Polycentropodidae																
Neureclipsis	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydropsychidae	1.7	4.1	3.3	5.2	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	1.7	4.1

continued . . .

Table 20. Continued.

Taxon	Station 1E		Station 1W		Station 2E		Station 2W		Station 3E		Station 3W		Station 4E		Station 4W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Hydroptilidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0
Brachycentridae																
Brachycentrus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diptera																
Chaoboridae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ceratopogonidae	0.0	0.0	3.3	5.2	0.0	0.0	16.7	40.8	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0
Chironomidae	190.0	226.3	118.3	138.2	261.7	247.6	155.0	186.0	135.0	126.0	81.7	94.5	113.3	69.8	118.3	101.1
Simuliidae	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	8.4
Athericidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1
Empididae	0.0	0.0	6.7	12.1	6.7	10.3	5.0	8.4	0.0	0.0	13.3	32.7	0.0	0.0	0.0	0.0
Muscidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0
TOTAL NUMBERS	433.3	583.3	225.0	142.2	445.0	342.4	350.0	196.8	298.3	169.3	335.0	333.9	291.7	170.3	241.7	169.6

continued . . .

Table 20. Continued.

Taxon	Station 5E		Station 5W		Station 6E		Station 6W		Station 7E		Station 7W		Station 8E		Station 8W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Nematomorpha	5.0	8.4	1.7	4.1	1.7	4.1	10.0	20.0	0.0	0.0	18.3	44.9	0.0	0.0	8.3	20.4
Oligochaeta	45.0	35.6	28.3	23.2	20.0	27.6	33.3	33.9	41.7	33.1	55.0	57.9	1.7	4.1	21.7	23.2
Hirudinea																
Erpobdellidae																
Nephelopsis	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gastropoda																
Lymnaeidae																
Lymnaea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bivalvia																
Sphaeriidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0
Hydracarina	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cladocera	0.0	0.0	0.0	0.0	8.3	20.4	8.3	20.4	8.3	20.4	0.0	0.0	0.0	0.0	0.0	0.0
Ostracoda	0.0	0.0	0.0	0.0	0.0	0.0	8.3	20.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Copepoda	0.0	0.0	0.0	0.0	8.3	20.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Collembola	16.7	25.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	8.2	0.0	0.0	0.0	0.0
Ephemeroptera																
Siphlonuridae																
Ameletus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1
Siphlonurus	20.0	27.6	11.7	28.6	0.0	0.0	0.0	0.0	8.3	20.4	3.3	8.2	3.3	8.2	1.7	4.1
Baetidae																
Baetis sp. A	0.0	0.0	0.0	0.0	0.0	0.0	16.7	40.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetis sp. B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetis sp. X	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloeon sp. 1	0.0	0.0	6.7	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloeon sp. 2	1.7	4.1	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pseudocloeon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heptageniidae																
Heptagenia	0.0	0.0	16.7	24.2	3.3	8.2	5.0	8.4	23.3	27.3	16.7	24.2	3.3	5.2	10.0	12.6
Rhithrogena	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3	32.7	1.7	4.1

continued . . .

Table 20. Continued.

Taxon	Station 5E		Station 5W		Station 6E		Station 6W		Station 7E		Station 7W		Station 8E		Station 8W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Ametropodidae																
Ametropus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1
Metretopodidae																
Metretopus	25.0	48.1	11.7	19.4	98.3	109.4	50.0	79.5	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0
Leptophlebiidae																
Leptophlebia	3.3	8.2	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ephemerellidae																
Ephemerella	0.0	0.0	8.3	7.5	3.3	5.2	5.0	12.2	1.7	4.1	8.3	20.4	5.0	5.5	1.7	4.1
Tricorythidae																
Tricorythodes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Caenidae																
Caenis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetiscidae																
Baetisca	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0
Odonata																
Gomphidae																
Ophiogomphus	1.7	4.1	0.0	0.0	1.7	4.1	1.7	4.1	3.3	5.2	1.7	4.1	0.0	0.0	1.7	4.1
Plecoptera																
Pteronarcidae																
Pteronarcys	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Perlodidae	8.3	16.0	73.3	25.8	10.0	12.6	135.0	164.7	23.3	25.0	58.3	45.4	36.7	38.8	68.3	74.4
Hemiptera																
Corixidae	6.7	8.2	0.0	0.0	1.7	4.1	1.7	4.1	0.0	0.0	0.0	0.0	3.3	8.2	0.0	0.0
Coleoptera																
Dytiscidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elmidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichoptera																
Polycentropodidae																
Neureclipsis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0
Hydropsychidae	0.0	0.0	6.7	8.2	0.0	0.0	3.3	5.2	0.0	0.0	0.0	0.0	3.3	5.2	10.0	20.0
Hydroptilidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brachycentridae																
Brachycentrus	1.7	4.1	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

continued . . .

Table 20. Concluded.

Taxon	Station 5E		Station 5W		Station 6E		Station 6W		Station 7E		Station 7W		Station 8E		Station 8W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Diptera																
Chaoboridae	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ceratopogonidae	0.0	0.0	3.3	5.2	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae	953.3	615.0	103.3	75.8	280.0	216.1	160.0	41.0	140.0	122.6	170.0	147.1	55.0	87.3	125.0	103.1
Simuliidae	11.7	20.4	11.7	14.7	0.0	0.0	13.3	24.2	8.3	20.4	21.7	33.7	1.7	4.1	220.0	476.3
Athericidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Empididae	6.7	8.2	6.7	8.2	8.3	20.4	10.0	16.7	0.0	0.0	1.7	4.1	3.3	5.2	11.7	20.4
Muscidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL NUMBERS	1108.3	707.4	293.3	70.0	450.0	296.3	463.3	186.2	263.3	121.9	360.0	218.6	130.0	129.0	485.0	483.8

Table 21. Benthic invertebrate abundance (number/m^2) at 16 sites on the Athabasca River between June 9 and June 24, 1981. Values are means and standard deviations based on 6 samples from each station.

Taxon	Station 1E		Station 1W		Station 2E		Station 2W		Station 3E		Station 3W		Station 4E		Station 4W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Nematomorpha	5.0	12.2	0.0	0.0	0.0	0.0	13.3	18.6	1.7	4.1	0.0	0.0	3.3	5.2	1.7	4.1
Oligochaeta	613.3	956.5	638.3	811.2	310.0	372.0	366.7	425.8	78.3	87.3	231.7	309.9	45.0	20.7	171.7	220.4
Hirudinea																
Erpobdellidae																
Nephelopsis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1
Hydracarina	0.0	0.0	0.0	0.0	5.0	5.5	0.0	0.0	0.0	0.0	11.7	20.4	1.7	4.1	1.7	4.1
Cladocera	0.0	0.0	3.3	5.2	11.7	24.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0
Ostracoda	0.0	0.0	0.0	0.0	36.7	43.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	20.4
Copepoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	20.4	0.0	0.0	0.0	0.0
Collembola	0.0	0.0	0.0	0.0	13.3	21.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	20.4
Ephemeroptera																
Siphlonuridae																
Ameletus	0.0	0.0	8.3	20.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	40.8	16.7	40.8
Analetris sp. 1	8.3	20.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Isonychia	0.0	0.0	0.0	0.0	16.7	40.8	0.0	0.0	3.3	5.2	25.0	32.1	18.3	21.4	8.3	13.3
Siphlonurus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetidae																
Baetis sp. A	0.0	0.0	23.3	48.0	15.0	23.5	16.7	32.0	106.7	140.5	78.3	66.2	101.7	161.8	16.7	19.7
Baetis sp. C	0.0	0.0	8.3	16.0	5.0	8.4	3.3	8.2	0.0	0.0	0.0	0.0	10.0	15.5	11.7	16.0
Baetis sp. D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0
Baetis sp. X	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	8.3	20.4	0.0	0.0
Centroptilum sp. 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	16.0	3.3	8.2	0.0	0.0	0.0	0.0
Cloeon sp. 1	0.0	0.0	0.0	0.0	30.0	48.2	0.0	0.0	15.0	23.5	0.0	0.0	0.0	0.0	1.7	4.1
Cloeon sp. 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pseudocloeon	0.0	0.0	0.0	0.0	1.7	4.1	1.7	4.1	3.3	5.2	0.0	0.0	26.7	41.3	15.0	22.6

continued . . .

Table 21. Continued.

Taxon	Station 1E		Station 1W		Station 2E		Station 2W		Station 3E		Station 3W		Station 4E		Station 4W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Heptageniidae																
Epeorus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heptagenia	10.0	24.5	8.3	7.5	30.0	26.1	30.0	26.1	118.3	114.6	281.7	115.3	290.0	284.0	250.0	303.6
Rhithrogena	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	5.0	5.5	0.0	0.0
Stenonema	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0
Ametropodidae																
Ametropus	0.0	0.0	30.0	64.2	13.3	20.7	80.0	82.9	23.3	38.3	6.7	16.3	0.0	0.0	0.0	0.0
Metretopodidae																
Metretopus	6.7	10.3	3.3	8.2	5.0	8.4	8.3	16.0	11.7	14.7	10.0	6.3	3.3	8.2	21.7	39.2
Ephemerellidae																
Ephemerella	0.0	0.0	1.7	4.1	0.0	0.0	10.0	1.0	1.7	4.1	6.7	5.2	11.7	19.4	16.7	13.7
Tricorythidae																
Tricorythodes	0.0	0.0	0.0	0.0	41.7	66.5	3.3	8.2	6.7	16.3	46.7	72.6	28.3	31.9	121.7	153.4
Caenidae																
Brachycercus	8.3	16.0	0.0	0.0	3.3	8.2	0.0	0.0	5.0	5.5	1.7	4.1	1.7	4.1	0.0	0.0
Caenis	0.0	0.0	0.0	0.0	98.31	166.2	0.0	0.0	3.3	8.2	13.3	32.7	1.7	4.1	31.7	77.6
Odonata																
Gomphidae																
Ophiogomphus	3.3	5.2	21.7	17.2	13.3	21.6	0.0	0.0	5.0	5.5	23.3	21.6	6.7	10.3	6.7	12.1
Plecoptera																
Perlodidae	1.7	4.1	40.0	51.8	5.0	5.5	40.0	33.5	36.7	24.2	51.7	33.1	95.0	82.9	30.0	40.5
Hemiptera																
Corixidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera																
Elmidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichoptera																
Hydropsychidae	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	1.7	4.1	11.7	13.3	10.0	20.0
Hydroptilidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	20.4	0.0	0.0
Brachycentridae																
Brachycentrus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0
Diptera																
Ceratopogonidae	16.7	15.1	35.0	43.2	15.0	12.2	20.0	25.3	26.7	16.3	8.3	11.7	6.7	8.2	0.0	0.0
Chironomidae	203.3	212.5	211.7	241.4	358.3	364.0	283.3	271.9	246.7	266.4	171.7	95.0	310.0	379.7	355.0	408.1
Simuliidae	1.7	4.1	10.0	15.5	5.0	8.4	1.7	4.1	6.7	16.3	3.3	5.2	28.3	34.9	0.0	0.0
Empididae	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL NUMBERS	878.3	1061.2	1046.7	1093.0	1033.3	978.9	880.0	658.9	708.3	539.2	990.0	396.3	1045.0	553.6	1106.7	1028.3

continued . . .

Table 21. Continued.

Taxon	Station 5E		Station 5W		Station 6E		Station 6W		Station 7E		Station 7W		Station 8E		Station 8W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Nematomorpha	1.7	4.1	3.3	8.2	8.3	20.4	0.0	0.0	5.0	12.2	0.0	0.0	0.0	0.0	1.7	4.1
Oligochaeta	563.3	670.5	140.0	173.7	98.3	114.3	110.0	171.1	41.7	47.9	141.7	108.0	198.3	250.7	211.7	348.6
Hirudinea																
Erpobdellidae																
Nephelopsis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydracarina	3.3	5.2	0.0	0.0	1.7	4.1	0.0	0.0	8.3	20.4	0.0	0.0	0.0	0.0	0.0	0.0
Cladocera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostracoda	28.3	40.2	1.7	4.1	0.0	0.0	8.3	20.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Copepoda	8.3	20.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Collembola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ephemeroptera																
Siphlonuridae																
Ameletus	0.0	0.0	0.0	0.0	1.7	4.1	15.0	19.7	3.3	8.2	5.0	8.4	0.0	0.0	0.0	0.0
Analetris sp. 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Isonychia	41.7	57.4	20.0	40.0	35.0	52.1	1.7	4.1	1.7	4.1	1.7	4.1	0.0	0.0	0.0	0.0
Siphlonurus	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetidae																
Baetis sp. A	40.0	78.7	8.3	7.5	25.0	28.1	0.0	0.0	23.3	25.8	20.0	26.1	1.7	4.1	1.7	4.1
Baetis sp. C	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0
Baetis sp. D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetis sp. X	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Centroptilum sp. 1	1.7	4.1	0.0	0.0	1.7	4.1	0.0	0.0	3.3	8.2	0.0	0.0	0.0	0.0	3.3	5.2
Cloeon sp. 1	30.0	46.9	1.7	4.1	18.3	18.3	6.7	10.3	58.3	59.1	1.7	4.1	1.7	4.1	0.0	0.0
Pseudocloeon	35.00	37.8	10.0	20.0	20.0	27.6	0.0	0.0	21.7	19.4	0.0	0.0	0.0	0.0	3.3	8.2
Heptageniidae																
Epeorus	0.0	0.0	3.3	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heptagenia	175.0	200.9	355.0	378.6	248.3	261.0	108.3	86.1	150.0	116.1	140.0	102.2	6.7	8.2	18.3	24.0
Rhithrogena	0.0	0.0	10.0	20.0	0.0	0.0	1.7	4.1	0.0	0.0	3.3	8.2	0.0	0.0	0.0	0.0
Stenonema	5.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

continued . . .

Table 21. Concluded.

Taxon	Station 5E		Station 5W		Station 6E		Station 6W		Station 7E		Station 7W		Station 8E		Station 8W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Ametropodidae																
Ametropus	21.7	33.7	0.0	0.0	3.3	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.7	33.3
Metretopodidae																
Metretopus	28.3	38.2	1.7	4.1	38.3	46.7	8.3	11.7	35.0	38.3	5.0	8.4	0.0	0.0	0.0	0.0
Ephemerellidae																
Ephemerella	16.7	19.7	15.0	12.2	8.3	13.3	8.3	13.3	1.7	4.1	0.0	0.0	6.7	12.1	0.0	0.0
Tricorythidae																
Tricorythodes	221.7	403.5	8.3	20.4	133.3	326.6	11.7	24.0	13.3	24.2	0.0	0.0	0.0	0.0	8.3	9.8
Caenidae																
Brachycercus	15.0	25.1	0.0	0.0	20.0	6.3	6.7	10.3	10.0	8.9	3.3	8.2	0.0	0.0	1.7	4.1
Caenis	170.0	195.3	0.0	0.0	211.7	224.6	13.3	28.0	105.0	153.6	13.3	32.7	3.3	5.2	23.3	52.4
Odonata																
Gomphidae																
Ophiogomphus	11.7	4.1	6.7	8.2	21.7	14.7	1.7	4.1	11.7	11.7	5.0	8.4	0.0	0.0	0.0	0.0
Plecoptera																
Perlodidae	13.3	19.7	30.0	51.4	30.0	24.5	35.0	76.1	20.0	30.3	18.3	11.7	0.0	0.0	13.3	28.0
Hemiptera																
Corixidae	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera																
Elmidae	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichoptera																
Hydropsychidae	0.0	0.0	11.7	19.4	25.0	41.8	1.7	4.1	0.0	0.0	10.0	12.6	0.0	0.0	10.0	20.0
Hydroptilidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brachycentridae																
Brachycentrus	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	8.4	0.0	0.0
Diptera																
Ceratopogonidae	6.7	8.2	6.7	8.2	3.3	5.2	0.0	0.0	10.0	8.9	0.0	0.0	1.7	4.1	5.0	12.2
Chironomidae	626.7	566.8	228.3	254.7	426.7	399.5	805.0	930.3	323.3	307.5	1005.0	1154.5	340.0	396.4	473.3	535.9
Simuliidae	1.7	4.1	16.7	24.2	3.3	5.2	0.0	0.0	0.0	0.0	0.0	0.0	10.0	20.0	10.0	24.5
Empididae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	8.2	1.7	4.1
TOTAL NUMBERS	2070.0	1903.3	880.0	850.1	1383.3	1285.9	1150.0	1051.8	846.7	450.4	1375.0	1210.9	578.3	632.8	813.3	970.7

Table 22. Benthic invertebrate abundance (number/m^2) at 16 sites on the Athabasca River between July 7 and July 22, 1981. Values are means and standard deviations based on 6 samples from each station.

Taxon	Station 1E		Station 1W		Station 2E		Station 2W		Station 3E		Station 3W		Station 4E		Station 4W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Cnidaria																
Hydroida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0
Nematomorpha	50.0	59.3	16.7	32.0	13.3	23.4	5.0	12.2	10.0	24.5	38.3	59.1	20.0	16.7	21.7	35.4
Oligochaeta	948.3	322.5	310.0	218.4	205.0	203.8	88.3	33.1	56.7	129.3	398.3	307.1	580.0	269.5	391.7	307.6
Bivalvia																
Sphaeriidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydracarina	0.0	0.0	3.3	5.2	8.3	20.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cladocera	3.3	5.2	1.7	4.1	10.0	20.0	30.0	43.4	103.3	99.9	56.7	85.5	18.3	28.6	0.0	0.0
Ostracoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.0	59.6	0.0	0.0
Copepoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	20.4	0.0	0.0	0.0	0.0
Collembola	0.0	0.0	76.7	134.6	1.7	4.1	8.3	20.4	25.0	41.8	18.3	28.6	8.3	20.4	3.3	8.2
Ephemeroptera																
Siphlonuridae																
Ameletus	1.7	4.1	1.7	4.1	0.0	0.0	10.0	24.5	0.0	0.0	48.3	60.1	0.0	0.0	50.0	58.0
Analetris sp. 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Analetris sp. 2	0.0	0.0	0.0	0.0	1.7	4.1	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Isonychia	90.0	127.0	15.0	22.6	8.3	13.3	3.3	8.2	31.7	35.4	125.0	251.0	18.3	24.0	83.3	101.7
Siphlonurus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetidae																
Baetis sp. A	33.3	36.7	33.3	48.9	0.0	0.0	0.0	0.0	10.0	20.0	1.7	4.1	8.3	13.3	1.7	4.1
Baetis sp. B	8.3	9.8	1.7	4.1	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0
Baetis sp. C	0.0	0.0	6.7	12.1	1.7	4.1	0.0	0.0	0.0	0.0	13.3	24.2	1.7	4.1	0.0	0.0
Baetis sp. D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetis sp. X	8.3	16.0	63.3	66.5	1.7	4.1	13.3	19.7	1.7	4.1	10.0	24.5	1.7	4.1	10.0	16.7
Centroptilum sp. 1	0.0	0.0	1.7	4.1	0.0	0.0	3.3	8.2	5.0	8.4	15.0	28.1	5.0	12.2	13.3	19.7
Centroptilum sp. 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloeon sp. 1	90.0	94.7	6.7	8.2	121.7	135.4	121.6	127.0	205.0	185.8	96.7	85.2	121.7	119.9	65.0	36.2
Cloeon sp. 2	1.7	4.1	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

continued . . .

Table 22. Continued.

Taxon	Station 1E		Station 1W		Station 2E		Station 2W		Station 3E		Station 3W		Station 4E		Station 4W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Pseudocloeon	3.3	5.2	11.7	13.3	23.3	22.5	35.0	54.3	5.0	8.4	33.3	43.7	0.0	0.0	13.3	19.7
Heptageniidae																
Heptagenia	295.0	307.2	156.7	88.7	196.7	180.4	153.3	119.4	310.0	52.2	328.3	339.5	120.0	87.4	170.0	151.7
Rhitrogena	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1
Ametropodidae																
Ametropus	0.0	0.0	8.3	11.7	840.0	1153.6	53.3	63.8	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0
Metretopodidae																
Metretopus	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Siphloplecton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leptophlebiidae																
Leptophlebia	0.0	0.0	1.7	4.1	10.0	24.5	8.3	20.4	11.7	20.4	8.3	20.4	0.0	0.0	0.0	0.0
Ephemerellidae																
Ephemerella	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	26.7	45.5	8.3	20.4	8.3	13.3	8.3	16.0
Tricorythidae																
Tricorythodes	76.7	85.0	128.3	161.5	111.7	112.3	63.3	61.9	168.3	206.2	56.7	60.2	141.7	113.6	36.7	35.6
Caenidae																
Brachycercus	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	20.7	0.0	0.0
Caenis	25.0	32.1	21.6	30.6	43.3	41.8	30.0	41.5	131.7	64.6	36.7	49.7	1.7	4.1	20.0	21.9
Ephemeridae																
Ephemera	0.0	0.0	3.3	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polymitarcyidae																
Ephoron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Odonata																
Gomphidae																
Ophiogomphus	25.0	21.7	20.0	15.5	30.0	16.7	18.3	22.3	5.0	5.5	30.0	17.9	5.0	8.4	10.0	15.5
Plecoptera																
Pteronarcidae																
Pteronarcella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pteronarcys	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Perlodidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	20.0	8.3	20.4	8.3	11.7	0.0	0.0
Hemiptera																
Corixidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera																
Elmidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0

continued . . .

Table 22. Continued.

Taxon	Station 1E		Station 1W		Station 2E		Station 2W		Station 3E		Station 3W		Station 4E		Station 4W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Trichoptera																
Polycentropodidae																
Neureclipsis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydropsychidae	65.0	107.5	11.7	24.0	5.0	5.5	0.0	0.0	15.0	23.5	13.3	24.2	8.3	13.3	13.3	19.7
Hydroptilidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brachycentridae																
Brachycentrus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diptera																
Tipulidae	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ceratopogonidae	0.0	0.0	13.3	8.2	3.3	5.2	1.7	4.1	0.0	0.0	3.3	8.2	0.0	0.0	1.7	4.1
Chironomidae	931.7	759.2	973.3	320.0	803.3	436.9	800.0	309.3	758.3	572.6	1490.0	581.5	1593.3	766.7	1295.0	597.9
Simuliidae	3.3	5.2	23.3	57.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	8.4	0.0	0.0
Empididae	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	1.7	4.1	6.7	12.1	5.0	5.5	0.0	0.0
TOTAL NUMBERS	2660.0	1582.8	1920.0	702.2	2443.3	1792.6	1448.3	377.8	1891.7	935.7	2853.3	1163.0	2738.3	1007.9	2210.0	1125.7

continued . . .

Table 22. Continued.

Taxon	Station 5E		Station 5W		Station 6E		Station 6W		Station 7E		Station 7W		Station 8E		Station 8W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Cnidaria																
Hydroida	0.0	0.0	0.0	0.0	16.7	25.8	0.0	0.0	28.3	69.4	0.0	0.0	0.0	0.0	0.0	0.0
Nematomorpha	11.7	19.4	20.0	31.6	41.7	59.8	5.0	12.2	56.7	30.8	38.3	61.1	20.0	24.5	10.0	20.0
Oligochaeta	928.3	680.2	306.7	323.1	311.7	132.3	535.0	237.1	581.7	931.4	2905.0	2661.3	1066.7	948.0	550.0	486.8
Bivalvia																
Sphaeriidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	8.4	0.0	0.0	0.0	0.0	0.0	0.0
Hydracarina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cladocera	103.3	77.4	13.3	24.2	216.7	233.9	10.0	20.0	268.3	254.3	1.7	4.1	8.3	20.4	0.0	0.0
Ostracoda	16.7	40.8	0.0	0.0	16.7	40.8	16.7	25.8	26.7	40.8	16.7	40.8	41.7	58.5	8.3	20.4
Copepoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	20.4	0.0	0.0	16.7	40.8	0.0	0.0
Collembola	33.3	60.6	0.0	1 0.0	1.7	4.1	1.7	4.1	10.0	20.0	16.7	25.8	0.0	0.0	0.0	0.0
Ephemeroptera																
Siphlonuridae																
Ameletus	48.3	113.6	1.7	4.1	1.7	4.1	3.3	5.2	13.3	19.7	16.7	40.8	0.0	0.0	0.0	0.0
Analetris sp. 1	0.0	0.0	0.0	0.0	0.0	0.0	16.7	25.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Analetris sp. 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Isonychia	23.3	36.1	10.0	20.0	0.0	0.0	13.3	17.5	5.0	5.5	0.0	0.0	0.0	0.0	0.0	0.0
Siphlonurus	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetidae																
Baetis sp. A	1.7	4.1	5.0	8.4	3.3	5.2	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	1.7	4.1
Baetis sp. B	0.0	0.0	0.0	0.0	0.0	0.0	3.3	8.2	0.0	0.0	5.0	8.4	0.0	0.0	0.0	0.0
Baetis sp. C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	36.7	8.3	20.4	0.0	0.0	0.0	0.0
Baetis sp. D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	8.4	0.0	0.0	0.0	0.0
Baetis sp. X	0.0	0.0	1.7	4.1	21.7	34.9	30.0	35.2	35.0	68.0	43.3	83.1	1.7	4.1	0.0	0.0
Centroptilum sp. 1	0.0	0.0	0.0	0.0	16.7	36.1	0.0	0.0	6.7	12.1	6.7	8.2	0.0	0.0	0.0	0.0
Centroptilum sp. 2	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloeon sp. 1	173.3	75.3	26.7	46.3	286.7	229.8	6.7	16.3	591.7	496.8	11.7	24.0	5.0	5.5	0.0	0.0
Cloeon sp. 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	1.7	4.1	8.3	20.4	0.0	0.0

continued . . .

Table 22. Continued.

Taxon	Station 5E		Station 5W		Station 6E		Station 6W		Station 7E		Station 7W		Station 8E		Station 8W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Pseudocloeon	25.0	51.7	10.0	20.0	0.0	0.0	0.0	0.0	8.3	11.7	10.0	20.0	0.0	0.0	1.7	4.1
Heptageniidae																
Heptagenia	213.3	300.5	113.3	92.2	51.7	51.5	616.7	673.5	323.3	228.7	401.7	193.2	13.3	8.2	56.7	73.9
Rhitrogena	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0
Ametropodidae																
Ametropus	1.7	4.1	1.7	4.1	0.0	0.0	0.0	0.0	11.7	20.4	0.0	0.0	0.0	0.0	1.7	4.1
Metretopodidae																
Metretopus	5.0	12.2	0.0	0.0	3.3	8.2	3.3	8.2	1.7	4.1	1.7	4.1	8.3	20.4	0.0	0.0
Siphloplecton	5.0	12.2	0.0	0.0	3.3	8.2	10.0	24.5	0.0	0.0	0.0	0.0	8.3	20.4	0.0	0.0
Leptophlebiidae																
Leptophlebia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	20.0	10.0	20.0	0.0	0.0	0.0	0.0
Ephemerellidae																
Ephemerella	10.0	20.0	0.0	0.0	0.0	0.0	8.3	20.4	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0
Tricorythidae																
Tricorythodes	165.0	203.3	1 6.7	12.1	78.3	88.9	68.3	92.6	225.0	342.3	125.0	85.5	6.7	8.2	10.0	8.9
Caenidae																
Brachycercus	6.7	16.3	0.0	0.0	0.0	0.0	5.0	8.4	1.7	4.1	1.7	4.1	0.0	0.0	0.0	0.0
Caenis	103.3	117.4	1.7	4.1	91.7	90.2	28.3	25.6	328.3	351.0	48.3	19.4	3.3	5.2	0.0	0.0
Ephemeridae																
Ephemera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	8.2	0.0	0.0	0.0	0.0	0.0	0.0
Polymitarcyidae																
Ephoron	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0
Odonata																
Gomphidae																
Ophiogomphus	16.7	15.1	3.3	5.2	18.3	21.4	10.0	15.5	20.0	14.1	15.0	16.4	0.0	0.0	1.7	4.1
Plecoptera																
Pteronarcidae																
Pteronarcella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0
Pteronarcys	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Perlodidae	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	16.7	40.84	0.0	0.0	10.0	20.0
Hemiptera																
Corixidae	0.0	0.0	0.0	0.0	5.0	5.5	0.0	0.0	10.0	24.5	0.0	0.0	1.7	4.1	0.0	0.0
Coleoptera																
Elmidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

continued . . .

Table 22. Concluded.

Taxon	Station 5E		Station 5W		Station 6E		Station 6W		Station 7E		Station 7W		Station 8E		Station 8W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Trichoptera																
Polycentropodidae																
Neureclipsis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0
Hydropsychidae	3.3	8.2	0.0	0.0	10.0	24.5	23.3	52.4	11.7	24.0	50.0	41.0	0.0	0.0	13.3	21.6
Hydroptilidae	0.0	0.0	0.0	0.0	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brachycentridae																
Brachycentrus	0.0	0.0	0.0	0.0	0.0	0.0	5.0	8.4	0.0	0.0	15.0	23.5	0.0	0.0	10.0	15.5
Diptera																
Tipulidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ceratopogonidae	3.3	5.2	1.7	4.1	0.0	0.0	5.0	5.5	1.7	4.1	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae	1975.0	2128.7	575.0	364.5	885.0	690.1	1961.7	1051.1	1880.0	893.3	5036.7	2342.2	2710.0	1668.4	1485.0	540.5
Simuliidae	8.3	20.4	38.3	89.1	16.7	25.8	0.0	0.0	1.7	4.1	0.0	0.0	0.0	0.0	1.7	4.1
Empididae	0.0	0.0	3.3	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL NUMBERS	3883.3	3420.6	1141.7	622.5	2100.0	415.7	3390.0	1810.1	4501.7	1896.0	8808.3	4056.5	3920.0	2413.2	2161.7	945.2

Table 23. Benthic invertebrate abundance (number/m^2) at 16 sites on the Athabasca River between August 18 and August 19, 1981. Values are means and standard deviations based on 3 samples from each station.

Taxon	Station 1E		Station 1W		Station 2E		Station 2W		Station 3E		Station 3W		Station 4E		Station 4W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Cnidaria																
Hydroida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nematomorpha	26.7	37.9	0.0	0.0	16.7	28.9	3.3	5.8	0.0	0.0	6.7	11.5	0.0	0.0	13.3	15.3
Oligochaeta	326.7	149.8	26.7	5.8	126.7	185.8	143.3	80.2	123.3	164.4	80.0	85.4	400.0	193.1	296.7	181.5
Bivalvia																
Sphaeriidae	20.0	26.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydracarina	3.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cladocera	0.0	0.0	23.3	23.1	0.0	0.0	16.7	28.9	1 0.0	0.0	16.7	28.9	33.3	57.7	0.0	0.0
Ostracoda	0.0	0.0	0.0	0.0	66.7	115.5	16.7	28.9	16.7	28.9	0.0	0.0	0.0	0.0	0.0	0.0
Amphipoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.8	0.0	0.0	0.0	0.0
Collembola	16.7	28.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ephemeroptera																
Siphlonuridae																
Ameletus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Analetris sp. 2	0.0	0.0	0.0	0.0	3.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Isonychia	3.3	5.8	6.7	11.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetidae																
Baetis sp. B	66.7	115.5	3.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetis sp. C	10.0	10.0	0.0	0.0	3.3	5.8	0.0	0.0	0.0	0.0	6.7	11.5	0.0	0.0	3.3	5.8
Baetis sp. X	33.3	41.6	26.7	46.2	26.7	25.2	20.0	26.5	66.7	30.6	60.0	26.5	113.3	35.1	56.7	35.1
Centroptilium sp. 1	0.0	0.0	26.7	25.2	0.0	0.0	10.0	17.3	3.3	5.8	0.0	0.0	6.7	5.8	0.0	0.0
Cloeon sp. 1	26.7	25.2	6.7	5.8	10.0	10.0	56.7	66.6	33.3	35.1	0.0	0.0	70.0	60.0	0.0	0.0
Cloeon sp. 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	34.6	0.0	0.0	0.0	0.0	0.0	0.0
Pseudocloeon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.8	0.0	0.0	10.0	10.0
Heptageniidae																
Heptagenia	293.3	80.2	93.3	32.1	213.3	206.5	86.7	15.3	206.7	104.1	380.0	182.5	360.0	151.3	343.3	133.2
Ametropodidae																
Ametropus	3.3	5.8	3.3	5.8	3.3	5.8	3.3	5.8	40.0	17.3	6.7	11.5	76.6	47.3	0.0	0.0
Metretopodidae																
Metretopus	0.0	0.0	0.0	0.0	3.3	5.8	6.7	11.5	6.7	5.8	0.0	0.0	16.7	15.3	0.0	0.0
Siphloplecton	0.0	0.0	0.0	0.0	0.0	0.0	6.7	11.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leptophlebiidae																

continued . . .

Table 23. Continued.

Taxon	Station 1E		Station 1W		Station 2E		Station 2W		Station 3E		Station 3W		Station 4E		Station 4W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Leptophlebia	0.0	0.0	0.0	0.0	23.3	40.4	6.7	11.5	3.3	5.8	23.3	25.2	0.0	0.0	0.0	0.0
Ephemerellidae																
Ephemerella	16.7	28.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tricorythidae																
Tricorythodes	6.7	11.5	0.0	0.0	16.7	28.9	3.3	5.8	23.3	32.1	6.7	11.5	46.7	47.3	6.7	5.8
Caenidae																
Caenis	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.8	6.7	5.8	0.0	0.0	13.3	15.3	0.0	0.0
Ephemeridae																
Ephemera	0.0	0.0	3.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hexagenia	0.0	0.0	20.0	34.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Odonata																
Gomphidae																
Ophiogomphus	13.3	15.3	40.0	26.5	23.3	5.8	26.7	11.5	10.0	10.0	30.0	10.0	20.0	10.0	16.7	11.5
Plecoptera																
Pteronarcidae																
Pteronarcella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.8	0.0	0.0	0.0	0.0
Perlodidae	200.0	78.1	83.3	32.1	23.3	32.1	16.7	15.3	43.3	28.9	150.0	62.4	86.7	60.3	140.0	110.0
Hemiptera																
Corixidae	0.0	0.0	0.0	0.0	3.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera																
Elmidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.8	0.0	0.0	0.0	0.0
Trichoptera																
Polycentropodidae																
Neureclipsis	0.0	0.0	3.3	5.8	3.3	5.8	10.0	10.0	0.0	0.0	10.0	10.0	0.0	0.0	0.0	0.0
Hydropsychidae	103.3	76.4	66.7	106.9	56.7	98.1	0.0	0.0	76.7	64.3	16.7	28.9	243.3	149.8	16.7	11.5
Brachycentridae																
Brachycentrus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	11.5	0.0	0.0	0.0	0.0
Leptoceridae																
Oecetis	3.3	5.8	0.0	0.0	3.3	5.8	3.3	5.8	0.0	0.0	30.0	34.6	0.0	0.0	0.0	0.0
Diptera																
Ceratopogonidae	60.0	87.2	3.3	5.8	23.3	25.2	276.7	20.8	30.0	52.0	46.7	56.9	70.0	52.9	26.7	20.8
Chironomidae	1050.0	290.5	106.7	15.3	1563.3	2046.8	1536.7	109.7	590.0	647.1	560.0	157.2	840.0	370.4	1230.0	656.4
Simuliidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Empididae	20.0	26.5	20.0	34.6	0.0	0.0	3.3	5.8	16.7	28.9	3.3	5.8	36.7	20.8	0.0	0.0
TOTAL NUMBERS	2303.3	339.5	563.3	201.3	2213.3	2776.7	2256.7	138.0	1316.7	1116.3	1453.3	293.0	2433.3	665.8	2160.0	821.6

continued . . .

Table 23. Continued.

Taxon	Station 5E		Station 5W		Station 6E		Station 6W		Station 7E		Station 7W		Station 8E		Station 8W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Cnidaria																
Hydroida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0
Nematomorpha	20.0	34.6	0.0	0.0	60.0	79.4	33.3	57.7	3.3	5.8	0.0	0.0	6.7	11.5	3.3	5.8
Oligochaeta	286.7	253.2	0.0	0.0	390.0	353.8	176.7	153.7	220.0	215.2	6.7	11.5	860.0	840.7	313.3	142.2
Bivalvia																
Sphaeriidae	3.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	30.0	26.5	0.0	0.0	0.0	0.0	0.0	0.0
Hydracarina	0.0	0.0	0.0	0.0	0.0	0.0	16.7	28.9	33.3	28.9	0.0	0.0	0.0	0.0	0.0	0.0
Cladocera	0.0	0.0	0.0	0.0	16.7	28.9	0.0	0.0	70.0	60.8	0.0	0.0	0.0	0.0	0.0	0.0
Ostracoda	0.0	0.0	0.0	0.0	16.7	28.9	0.0	0.0	66.7	76.4	0.0	0.0	0.0	0.0	0.0	0.0
Amphipoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Collembola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ephemeroptera																
Siphlonuridae																
Ameletus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0
Analetris sp. 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Isonychia	23.3	23.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetidae																
Baetis sp. B	0.0	1 0.0	0.0	0.0	3.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetis sp. C	3.3	5.8	3.3	5.8	3.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.8
Baetis sp. X	40.0	34.6	0.0	0.0	33.3	41.6	3.3	5.8	83.3	30.6	120.0	0.0	3.3	5.8	3.3	5.8
Centroptilum sp. 1	3.3	5.8	3.3	5.8	3.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloeon sp. 1	43.3	20.8	60.0	103.9	10.0	10.0	36.7	46.2	173.3	149.8	3.3	5.8	0.0	0.0	16.7	28.9
Cloeon sp. 2	3.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pseudocloeon	16.7	11.5	0.0	0.0	26.7	37.9	0.0	0.0	6.7	11.5	3.3	5.8	0.0	0.0	0.0	0.0
Heptageniidae																
Heptagenia	230.0	91.7	100.0	45.8	166.7	70.9	320.0	275.0	386.7	49.3	120.0	12.3	3 3.3	1 5.8	116.7	46.2
Ametropodidae																
Ametropus	3.3	5.8	3.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.8
Metretopodidae																
Metretopus	0.0	0.0	6.7	5.8	0.0	0.0	3.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Siphloplecton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leptophlebiidae																
Leptophlebia	10.0	10.0	0.0	0.0	33.3	41.6	6.7	5.8	63.3	47.3	10.0	17.3	0.0	0.0		0.0

continued . . .

Table 23. Concluded.

Taxon	Station 5E		Station 5W		Station 6E		Station 6W		Station 7E		Station 7W		Station 8E		Station 8W	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Ephemerellidae																
Ephemerella	0.0	0.0	0.0	0.0	20.0	26.5	0.0	0.0	0.0	0.0	6.7	11.5	0.0	0.0	0.0	0.0
Tricorythidae																
Tricorythodes	33.3	40.4	16.7	28.9	16.7	11.5	0.0	0.0	60.0	36.1	0.0	0.0	0.0	0.0	0.0	0.0
Caenidae																
Caenis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ephemeridae																
Ephemera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hexagenia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Odonata																
Gomphidae																
Ophiogomphus	33.3	5.8	26.7	11.5	30.0	36.1	6.7	11.5	66.7	23.1	23.3	20.8	0.0	0.0	6.7	5.8
Plecoptera																
Pteronarcidae																
Pteronarcella	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Perlodidae	10.0	10.0	16.7	28.9	6.7	11.5	26.7	37.9	0.0	0.0	13.3	5.8	0.0	0.0	16.7	15.3
Hemiptera																
Corixidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.8	0.0	0.0
Coleoptera																
Elmidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichoptera																
Polycentropodidae																
Neureclipsis	3.3	5.8	6.7	5.8	36.7	32.1	3.3	5.8	26.7	11.5	0.0	0.0	0.0	0.0	0.0	0.0
Hydropsychidae	36.7	32.1	63.3	1 5.8	46.7	64.3	33.3	57.7	3.3	5.8	66.7	47.3	2 0.0	1 0.0	60.0	65.6
Brachycentridae																
Brachycentrus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	11.5
Leptoceridae																
Oecetis	0.0	0.0	0.0	0.0	6.7	11.5	3.3	5.8	10.0	17.3	3.3	5.8	0.0	0.0	6.7	5.8
Diptera																
Ceratopogonidae	13.3	5.8	6.7	5.8	20.0	17.3	33.3	15.3	30.0	17.3	0.0	0.0	3.3	5.8	0.0	0.0
Chironomidae	1093.3	441.1	493.3	339.5	793.3	359.5	2233.3	1810.5	2953.3	917.7	1410.0	334.1	5970.0	1542.1	1070.0	432.1
Simuliidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.8
Empididae	0.0	0.0	16.7	28.9	43.3	37.9	86.7	68.1	3.3	5.8	0.0	0.0	0.0	0.0	6.7	5.8
TOTAL NUMBERS	1910.0	646.3	823.3	454.5	1783.3	1101.1	3023.3	1954.30	4310.0	1482.0	1786.7	191.4	6850.0	2231.1	1636.7	420.3

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